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# **Developing the Tools to Meet the Nation's**

## **Monitoring Needs:**

### **The Evolution of EMAP**

Third Environmental Monitoring and Assessment  
Program (EMAP) Research Symposium

April 8-11, 1997

Omni Albany Hotel  
Albany, NY

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***EMAP Symposium Invited Speakers***

## Environmental Data in Decision Making in EPA Regional Offices

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The Mid-Atlantic region of the United States has a wide diversity of natural resources. Human pressures on these natural resources are intense. These factors have resulted in the collection of substantial amounts of environmental information about the region by EPA (both Regional and Research Offices), other governmental agencies, industry, and environmental groups. EPA Regional Offices comprehend first hand the importance of environmental data and are extremely supportive of investments in these data. Environmental data are critically important to EPA Regional Offices and are used prominently in a variety of strategic planning and resource management initiatives. In EPA Region 3, the use of scientifically-sound environmental data is, in fact, one of our strategic programmatic goals. Environmental information is captured and assessed continuously by Regional staff, sometimes working in partnership with other Federal and State agencies, to derive relevant resource management conclusions. The restoration goals for the Chesapeake Bay are based on environmental indicators and resulting data. Attainment of the water quality objectives for streams and coastal estuaries are predicated on monitoring data. Our initiative in the Mid-Atlantic Highlands area currently in the planning stages uses environmental indicators to measure the condition of their forests and streams. Future enhancements including landscape-level information will provide new opportunities for the use of data in planning and management activities. Significant value is added to these data during their use by Regional managers. The initiation of several Regional programs, such as the Chesapeake Bay Program and several National Estuary Programs, are founded in environmental data. Environmental information is used by the Regional program managers to ascertain whether programs are accomplishing their intended objectives. Finally, Regional programs provide a crucial means for disseminating this information to broad segments of the public, so that a better informed and educated client base for effective environmental protection will develop.

## **The Star Program: Universities and the U.S. EPA Partnership in Research**

Barbara M. Levinson

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U.S. EPA Center for Environmental Research and Quality Assurance (NCERQA) was created in 1995 as a result of a reorganization of the Office of Research and Development. NCERQA manages, among other programs, Science to Achieve Results (STAR), which includes Fellowships, Exploratory Grants, targeted research through Requests for Applications (RFAs), and the Centers of Excellence Program. The RFAs (commonly called "the Grants Program") is the largest part of the STAR program with funding increasing from \$22M in 1995, to \$55M in 1996, to a projected \$70M in 1997. STAR is committed to include the best scientists from this country's universities and non-profit centers, and to ensure the highest possible quality of science in areas of highest risk and greatest importance to the Agency. The topics for the RFAs are directed specifically towards national environmental science needs, as related to the mission of the Agency. These topics are selected to complement the EPA in-house research program. Many of these RFAs are advertised jointly with other Agencies. The Exploratory Grants program complements the RFAs by soliciting in broad, non-targeted areas related to the mission of the Agency. Awards are based on scientific peer review, relevancy to Agency mission, balance of research portfolio, and complementarity to EPA's in-house research program.

## **Examination of CASTNet Ambient Air Concentration Data for the Eastern US: 1989 - 1995**

J. E. Sickles, II, David Holland, Peter Principe, Ralph Baumgardner, Gardner Evans, and  
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In 1990 the Clean Air Act Amendments (CAAA) called for a monitoring program to assess improvements in the nation's air quality and overall environment. To meet this challenge, an integrated program was developed to reflect the interagency, intergovernmental, and international requirements of large-scale monitoring and assessment. An important component of this multi-agency activity is the Clean Air Status and Trends Network, CASTNet, developed by the EPA in coordination with NOAA. CASTNet goals were to establish an effective monitoring and assessment network to determine the status and trends of air pollution levels and their environmental effects and to develop a scientific database to improve understanding of causality for policy considerations. Currently, CASTNet monitoring activities focus mainly on air quality measurements and supporting meteorological measurements at some 51 sites located mainly in the eastern U.S. A relatively complete data record exists for the period 1989 through the third quarter of 1995 for 38 sites, 35 in the East. This presentation will focus on describing the spatial and temporal distributions of SO<sub>2</sub>, SO<sub>4</sub><sup>=</sup>, HNO<sub>3</sub>, and NO<sub>3</sub><sup>-</sup> in the eastern U.S. between 1989 and 1995. Site-specific trends in species concentrations will be presented. Annual and seasonal distributions of species concentrations will be shown, and summer and winter behaviors will be compared.

## Ozone Indicators of Forest and Arid Ecosystems

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Ozone in the troposphere has been well documented to injure susceptible plant species. The process of identifying these species is ongoing and involves field surveys and controlled exposure studies to identify and verify the injury response of these species to ozone. Only then can field studies be conducted to directly evaluate effects of ozone, or confirm predicted effects from models. Responses of sensitive species to ozone typically include foliar injury symptoms, reduction in foliage retention, accelerated senescence of foliage, reductions in growth, increased mortality, and in some cases alterations of plant communities. In mixed-conifer forests of California and Arizona, ozone has been shown to cause negative impacts. In southern California the effects range from foliar injury to alterations in forest community structure, especially at sites closest to Los Angeles metropolitan complexes. In the Eastern United States, some tree, shrub, and herb species are sensitive to ozone, and consistently exhibit foliar injury symptoms. It is not yet accepted, however, that growth of these species has been affected and subsequent changes in plant communities have occurred. Some controlled exposure studies suggest it is likely these effects have occurred. In arid lands of the Western U.S., a few species are susceptible to ambient-level ozone exposures. Foliar injury has been found on shrubs of one species in the California deserts when ambient ozone concentrations have been elevated. Since ozone injury is primarily dependent on foliar uptake of ozone in the process of photosynthesis during daylight hours when ozone is highest, arid species at highest risk are probably those metabolically most active during the spring and summer months when ozone concentrations are highest. For example, spring and summer annuals, riparian vegetation, and vegetation with mesophilic foliage are most likely to be susceptible.

## Aquatic Effects of Acidic Precipitation--The Recent Maine Story

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In Maine, high quality complete chemical data suitable for time series trend analysis has been available for wet precipitation since 1980 (NADP), for lakes since 1982 (LTM and successors), and for streams since 1987 (Bear Brooks). For precipitation for 1981-1989, Ca\*, Mg\*, Na, K\*, Cl, NO<sub>3</sub>, and SO<sub>4</sub> all decreased at the three NADP sites; those with a \* decreased at one or more sites at a significance level of 0.10 or less. During approximately the same period, five inland lakes (LTM) had increased ANC of 1.8 meq/L/yr, 11 maritime lakes in Acadia National Park had increased ANC of 5.5 meq/L for [(1988-9 mean)-(1982-4 mean)]. East Bear Brook has decreased ANC from 1987 to 1996. SO<sub>4</sub> decreased in all three data sets. ANC is defined as: S(Base cations) - S(Strong acid anions) or S(Weak acid anions)-(Acid cations). Thus ANC may be changed by variations in virtually any water chemistry parameter. The changes in ANC are rarely explained by a single variable. For example, the increase in the ANC for the five LTM lakes was accompanied by decreased SO<sub>4</sub> but a decrease also occurred in S(Base cations) of comparable magnitude and should have had an offsetting effect on ANC. Therefore, other variables and processes may be critical to the small changes in ANC or pH in these acid-sensitive systems. They include unmeasured changes in inputs (fog, dry deposition, occult deposition), altered DOC quality and quantity, climate change effects (T and H<sub>2</sub>O), altered retention or transformation of N, and soils reflecting natural pedogenesis or altered vegetative communities at different sites. For example, East Bear Brook appears to be still acidifying with reduced SO<sub>4</sub> input but chronic retention of N, perhaps because the soils have not yet reached equilibrium with even the current reduced SO<sub>4</sub> loading.

## **Nitrogen Deposition in the Eastern U.S.: Potential Future Effects on the Acidity of Lakes and Streams**

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Future phases of the Clean Air Act may allow trading emissions reductions of NO<sub>x</sub> for emissions reductions of SO<sub>2</sub>. The potential environmental tradeoffs of such an option are hard to quantify. To address this question, we developed an approach to estimate the relative effects of nitrogen and sulfur deposition on regional-scale acidification of surface waters in the eastern United States. We modified the MAGIC model to allow estimation of the relative effects on lake and stream chemistry of varying times to N-saturation of surrounding forested watersheds and used the modified model to test a variety of assumptions concerning times to N saturation and levels of N and S deposition. We explored scenarios of times to watershed N saturation of 50, 100, and 250 years as well as a scenario of "no change" from current annual watershed N retention. We tested an inclusive matrix of ranges of S and N deposition from current levels down to background levels. We also modeled potential effects of decreased base cation deposition. We modeled a subset of the watersheds studied within EPA's Direct/Delayed Response Project. Our subset consisted of 95 catchments (statistically representing 6,324 lake or stream watersheds) in the Adirondacks region, Mid-Appalachian mountains, and the Southern Blue Ridge Province of the eastern United States. Our modeling indicated that for times of watershed N saturation of 50-100 years, projected effects of N deposition by the year 2040 may rival or exceed projected effects of S deposition.



## **EPA's UVB Monitoring Program: What Have We Learned to Date?**

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Measuring ultra-violet (UV) radiation presents a number of technical challenges. Across the range of wavelengths known as the UV-B range (280-315 nm), the intensity of the radiation varies by four orders of magnitude. Building an instrument to measure across this wide range of intensities is a challenging effort compounded by two additional factors: (1) The amount of light absorbed by ozone, the principal source for the "drop off" in intensity, is highly dependent on the wavelength: thus measurements must be very accurate, both in regard to the intensity and the wavelength being measured. (2) Action spectra, the relationship between the intensity of the radiation at a particular wavelength and the resulting effect, are also highly dependent on the wavelength and differ substantially depending on the effect of concern: matching UV-B intensity data to a variety of action spectra requires that the measurements be both spectrally resolved and accurate. Working collaboratively with the University of Georgia (UGA), the National Institute for Standards and Technology (NIST), the National Oceanic and Atmospheric Administration (NOAA) and other federal agencies, new standards and calibration techniques have been developed that allow calibrations of UV spectroradiometers to be "traceable" to NIST standards. These standards and calibration protocols allow the EPA UV network, using Brewer spectroradiometers, to produce reliable and accurate data needed to support studies of diverse effects and to understand and characterize the major contributing sources to variations in UV intensity. Working collaboratively has also produced the following: 1) a National UV Index with NWS of NOAA, 2) a UV chemical dosimeter with Clarkson University, 3) a UV DNA dosimeter with the Florida Institute of Technology, 4) a paper on the characterization of eastern rural aerosols on UV absorption.

## Phase Transitions in Forest Fragmentation: Implications for Restoration Opportunities at Regional Scales

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Where the potential natural vegetation is forest across a region, it can be divided into smaller units (e.g., counties, watersheds) and a graph of the proportion of forest in the largest patch (ordinate) versus the proportion in anthropogenic cover (abscissa) can be used as an index of forest fragmentation. If forests are not fragmented beyond that converted to anthropogenic cover, there would be only one forest patch in a unit and its proportional size would equal 1 minus the percent anthropogenic cover. Land cover data for the mid-Atlantic States of Pennsylvania, West Virginia, Maryland, Delaware, and Virginia were divided into watersheds to graph the proportion in the largest forest patch versus the proportion in anthropogenic cover. When anthropogenic cover was less than 37 percent, the proportional size of the largest forest patch more closely approximated the "ideal" state of 1 minus percent anthropogenic cover. As the proportion of anthropogenic land cover increased beyond 37 percent the size of the largest forest patch began to depart more dramatically from the ideal of 1 minus percent anthropogenic cover. The potential for increasing the proportional size of the largest forest patch by connecting two or more disjunct forest patches was low when percent anthropogenic cover was low, highest at moderate proportions of anthropogenic cover, and again low as the proportion of anthropogenic cover increased toward 100 percent. These results support the conceptual relationship that the potential for increasing forest connectivity is highest at moderate proportions of anthropogenic land cover because there tends to be two or more large but disjunct forest patches. The potential for increasing forest connectivity dropped off dramatically at 35 percent anthropogenic land cover, showing general agreement with the 37 percent transition threshold where the proportional size of the largest forest patch began to depart dramatically from the ideal of 1 minus percent anthropogenic cover.

## **Regional Land Cover Characterization Using Landsat and Other Spatial Data Input**

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As part of the activities of the Multi-Resolution Land Characteristics (MRLC) Interagency Consortium, an intermediate-scale land cover data set is being generated for the conterminous United States. This effort is being conducted on a U.S. Standard Federal Region by Standard Federal Region basis. To date, land cover data sets have been generated for Regions 3 (Pennsylvania, West Virginia, Virginia, Maryland, Delaware) and 2 (New York and New Jersey). Classification work is currently underway in Federal Region 4 (the southeastern United States), and there are also plans to initiate land cover mapping activities in Regions 5 (the Great Lakes region) and 1 (New England) later this year. It is anticipated that a land cover data set for the entire conterminous United States will be completed by 1999. A standard land cover classification legend is being used, which is analogous to and compatible with other classification schemes. Approximately 22 land cover classes are being targeted. The primary source of data for the project is the Landsat thematic mapper (TM). For each region, TM data sets representing both leaf-on and leaf-off conditions are acquired, preprocessed and georeferenced to MRLC specifications. Mosaicked data are clustered using unsupervised classification, and individual clusters are labeled using aerial photographs. Individual clusters that represent more than one land cover unit are split using spatial modeling employing multiple ancillary spatial data layers (most notably digital elevation model, population, land use and land cover, and wetlands information). The approach yields regional land cover information suitable for a wide array of applications, including landscape metric analyses, policy development and modeling nutrient/pesticide runoff.

## **Using Landscape Characterization Information for Risk Assessment of Oil and Gas Development in Siberia, Russia**

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Oil exploration and production activities can potentially harm the fragile Arctic and Subarctic environment. The United States and Russia have monitored these areas for several decades using national security systems (NSS). The NSS data can be used to produce Geographic Information Systems which are a tool to predict environmentally consequences of oil exploration. As a result of the Gore-Chernomyrdin environmental initiative U.S. and Russian government agencies and oil industry are co-operating to improve risk assessment methodology and environmental regulations. Priobskoye was chosen as a test site to demonstrate the benefits of co-operation using GIS and risk assessment methodology. Combined U.S.-Russian GIS databases were made of the Priobskoye Oil Field. The national systems data were invaluable for the high resolution GIS of the oil field. The subsequent risk assessment of the Priobskoye oil field demonstrates the benefits of this approach. In particular, these results can be extended to other areas to enable managers to balance economic and environmental factors during oil exploration, production, and decommission activities.

## **Exploring Associations Among Mid-Atlantic Stream Indicators Using Dynamic Multi-Variate Graphic Mapping in a Highly Immersive Virtual Reality Environment**

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Geography inherently fills a 3-D space and yet we struggle with displaying geography using, primarily, 2-D display devices. Virtual environments offer a more realistically-dimensioned display space, and this is being realized in the expanding area of research on 3-D geographic information systems (GIS). Traditionally a GIS has only limited tools for statistical analysis, and 3-D GIS research has concentrated on the visualization of the geography. Here we discuss linking multivariate statistical graphics to geography in the highly immersive C2 environment at Iowa State University using mid-atlantic streams data.

## **A National Inter-Agency Vision for Terrestrial Inventory and Monitoring: A Statistical Perspective**

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A demonstration project in Oregon examined the feasibility of combining Federal environmental monitoring surveys. A merger should remove duplication of effort and reduce the potential to provide conflicting information to policy makers and to the public. Crews made photo interpretation measurements and ground soil/vegetation observations on sites that were selected from the Forest Inventory and Analysis (FIA), National Forest System (NFS) Region 6, and National Resource Inventory (NRI) surveys in a six-county area in Northern Oregon. A National Biological Service (NBS) crew made animal observations on those sites that were on Federal lands. The project benefited additionally from the active participation of other Federal agencies. A selection of variables were collected to characterize such things as land use, site description, forest and rangeland health, soil quality, vegetation profiles and animal abundance. The project demonstrated the feasibility of conducting a combined FIA/NRI survey. It established a framework for estimating the extent of forest and rangeland. It established a common database with uniform information, and it made substantial progress on defining a common set of measurements, protocols and field testing procedures.

## **Nutrients and Pesticides in the Nation's Waters: A National Assessment by the U.S. Geological Survey**

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After a 5-year development period, the U. S. Geological Survey (USGS) began full operation of its National Water Quality Assessment (NAWQA) Program in 1991. The goals of the NAWQA Program are to: 1. Describe current water-quality conditions for a large part of the freshwater streams, rivers, and ground-water aquifers of the United States. 2. Describe how water quality is changing over time. 3. Improve understanding of the primary natural and human factors that affect water-quality conditions. 4. Identify the implications of these results for the management of water resources. The NAWQA design provides consistent and comparable information on water resources in 60 of the largest and most important hydrologic systems in the United States. Individual investigations in these 60 areas are coordinated in design and approach to allow regional and national assessments. Using data existing prior to NAWQA along with findings from the first 20 study units, a first assessment of concentrations of pesticides and nutrients in ground and surface waters across the country is presented. Some of the design and statistical issues involved in the assessment, as well as its findings, are discussed.

## **Development and Validation of Ecological Indicators: An ORD Strategy**

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The Office of Research and Development (ORD) has formed an Ecological Indicators Working Group (WG) that is represented by all four ORD National Laboratories. The WG has three primary objectives: (1) An ORD strategy for research in ecological indicators is being developed by Division research scientists within and across resource types (landscape). This will establish the priorities and goals for indicator development for both intramural and extramural programs. Indicator research will be developed through the Risk Assessment Paradigm and Ecological Health Criteria. Efforts on the indicators of highest ecological significance that are most sensitive to change caused by anthropogenic stress. (2) Guidelines and procedures are being recommended to evaluate indicators for use in monitoring programs; the four proposed phases of indicator evaluation include conceptual soundness, implementation, statistical performance and interpretation/utility. It is anticipated that the evaluation guidelines will be useful for all organizations that apply indicators in ecological assessment as well as for ORD research prioritization. (3) Interactions with other organizations (states, program offices and regions) is ongoing and recognized as imperative for establishing indicator priorities, technical transfer, and developing usable and understandable guidelines for indicator evaluation and application. Interactions with other federal agencies in developing indicators for regional and national monitoring is a long-term goal.



## **A Eutrophication Index for Shallow Estuaries and Coastal Waters**

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While the characteristics of eutrophication appear self-evident, frequent, multiple measurements must be conducted over at least one annual cycle to quantify degree of eutrophication. Thus, mephitic algal concentrations, hypoxia and anoxia are temporally variable and single observations do not indicate eutrophication. A quantitative scale, which integrated multiple responses, would save time, expertise, and money, and would prove useful in water quality evaluations. We have attempted such a scale to evaluate eutrophication in shallow, polyhaline estuaries. The index was developed with a calibration data set collected during the summer of 1993 from the Delaware-Maryland Coastal Bays. Candidate chemical and biological indicators of eutrophication were selected based upon comparisons of values at previously defined oligotrophic and eutrophic sites in the calibration data set. Eight indicators were selected for the index: total dissolved nitrogen and phosphorus, total particulate nitrogen and phosphorus, total particulate carbon, chlorophyll a, oxygen saturation and sediment organic carbon. For each indicator, threshold values for five levels of eutrophication were identified based on values at test sites in the calibration data set. The index was validated using data from a long-term nutrient addition experiment conducted in experimental mesocosms. The index differentiated oligotrophic and eutrophic in calibration and verification data sets with a few summer measurements. This index should be extensively field tested to evaluate its utility as an inexpensive, rapid indicator of eutrophication.

## **Diatom Indicators of Stream and Wetland Stressors in a Risk Management Framework**

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The use of bioindicators that spatially and temporally integrate environmental signals is particularly important for assessment of stressors in shallow water habitats, like streams and wetlands, because physical and chemical characteristics vary with a high frequency. Despite this high frequency of variability in abiotic characteristics of habitats, diatoms were successfully related to physical and chemical conditions in both streams and wetlands in several geographic regions. In EMAP surveys of streams in the Mid-Atlantic Highlands, diatom autecological indices were successfully constructed to infer pH and TP in the streams. In surveys of 100 wetlands in Michigan and Kentucky, diatom autecological indices were able to infer conductivity and TP. In addition, diatoms assemblages may be able to infer the dominant vegetation type in the wetland. Results of our work in a variety of habitats suggest that bioindicators based on diatom species composition are more precise assessments of environmental stressors in streams and wetlands than one-time sampling of physical and chemical conditions. Long-term objectives of integrating bioindicators in a risk assessment/management framework will be presented. This framework presents an organized system of indices of stressors, indices of human activities that produce multiple stressors, and metrics for ecosystem integrity and sustainability. This framework will enable more precise characterizations of ecological risk, better informed evaluation of management options, and more successful management decisions.

## **A Zooplankton N:P Ratio Ecosystem Indicator for Lakes**

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The supply rates of nitrogen and phosphorus provide a scaling factor for linking landscape level ecosystem processes with local species responses in aquatic ecosystems. Resource supply theory is used to interpret variation in food web structure of freshwater zooplankton. Nitrogen and phosphorus are critical and often limiting constituents of organisms and comprise important biomolecules like nucleic acids, proteins, lipids, ATP, and structural carbohydrates like chitin. The N and P requirements among zooplankton species vary with life history, body size, and trophic position but are constant within a species. This constancy provides the basis by which different guilds of zooplankton can be directly correlated with ambient lake N:P ratios and indirectly correlated with watershed characteristics and stressors. Deviations from N:P supply rates expected from the watershed with N:P ratios in lake water can be used to evaluate both the type and magnitude of disturbance. The zooplankton-N:P indicator should provide a relatively rapid and simple method for inference of the structure of the pelagic assemblage including an index for the number of linkages and chain length in the web. Other correlates of both the N:P ratio and pelagic assemblage that reflect anthropogenic stress can then be used to further evaluate ecosystem condition and risks. Typical well-correlated risks include efficiency in pollutant transfer and biomagnification of toxics, loss of the cool-water refuge and food web simplification, increased algal turbidity, and increased UVB penetration due to anthropogenic acidification.

## Vegetation, Soil, and Animal Indicators of Rangeland Health

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We studied indicators of rangeland health on benchmark sites with long, well documented records of protection from disturbance or histories of disturbance and vegetation change. We measured ecosystem properties (metrics) that were clearly linked to ecosystem processes. We focused on retention of water and nutrients as key processes in healthy ecosystems. Metrics included in evaluation of rangeland health included: sizes of unvegetated patches, cover of short-lived and long-lived perennial grasses, cover and species composition of shrubs, cover of palatable species (for livestock), soil compaction, soil surface stability, and infiltration potential. We present examples of responses of these metrics on disturbance gradients in order to examine the sensitivity of the metrics as indicators. Community structure of breeding birds and of ants were studied as potential indicators. These animals did not exhibit interpretable variation on disturbance gradients and were judged not suitable as indicators of rangeland health.

## **The Development of Biological Indicators in Response to State Water Resource Management Objectives**

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Managing for the protection and restoration of aquatic life in surface waters is an important objective for state water quality agencies. However, objective and robust indicators and assessment criteria have been lacking. Biological criteria (biocriteria) were adopted in the Ohio water quality standards regulations in May 1990 and are based on the measurable characteristics of aquatic communities such as structural and functional attributes. Fish and macroinvertebrates are used to assess the biological integrity of surface waters, mainly rivers and streams, throughout Ohio. Numerical biological criteria were derived using data from "least impacted" regional reference sites. This design reflects the practical definition of biological integrity as the biological performance exhibited by the natural habitats of a region. Further organization and stratification of these criteria were accomplished using ecoregions. Data from more than 350 reference sites were used to establish attainable, baseline expectations within the framework of an existing system of aquatic life use designations. Biocriteria provide the impetus and opportunity to recognize and account for natural, ecological variability in the environment, something which previously was lacking in state water quality management programs. Having biological criteria has allowed our management programs to take into account the influence of ecoregions, river and stream size, and habitat in establishing baseline aquatic life use objectives. This represents a shift from the traditional chemical-based approach in which single criteria are applied unilaterally to these different situations. This approach has profoundly influenced strategic planning and priority setting, water quality based permitting, water quality standards, basic monitoring and reporting, nonpoint source assessment, and problem discovery within Ohio EPA.

## First Steps Toward an Impossible Mission: A Regional Environmental Scorecard

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EPA Region 3 and Office of Research and Development began a multi-year initiative in 1996 to:

- Improve the quality of environmental science and promote use of "good science" in environmental decision-making
- Characterize ecological resource conditions
- Report on status of environmental progress through a series of State-of-Region scorecards

Production of such a scorecard requires a coordinated, integrated approach that builds upon assessments on four (4) levels that increases in sophistication and complexity. Level I is the assessment of individual ecological resources such as estuaries, streams/rivers, forests, agroecosystems, land cover, landscape ecology, groundwater, wetlands, and birds. Level II assessments would, within each ecological resource area, conduct association between resource conditions (Level I) and stressors. Mid-Atlantic Integrated Assessments (MAIA) has work underway to address the known condition of these resources (Level I) as well as the Level II stressors association. For Level III assessments, the MAIA is presently integrating land cover and landscape activities with the ecological condition of individual groups at geographic scales from Region-wide to local communities. Level IV assessments will attempt to integrate stressor effects and associations among ecological resources. MAIA's progress to date on Level IV has focused upon exploring alternative conceptual models for integration across ecological resource areas.

In September 1966, Vice President Al Gore challenged federal agencies to work with the scientific community, State and local agencies and non-governmental organizations to produce a "report card" on the health of our Nation's ecosystems by 2001. Many consider this scorecard goal an unrealistic request that can not be completed with much accuracy or scientific foundation, a real mission impossible. The MAIA program has nonetheless attempted to respond to this challenge and evaluate the status and trends of our regional ecosystems such as: wetlands, surface waters and lakes, estuaries, forests, agriculture, fisheries, land cover, landscape, groundwater, and birds. This is a daunting task, but MAIA is now partnering with federal agencies, States, non-profit organizations and local communities, characterizing through sound science the environmental condition of ecological resources and associated stressors as well as the connection to land cover and landscape changes. Assessment results are now available in key areas and will be available in others in the next few years.

## **State of the Estuaries in the Mid-Atlantic Region of the United States**

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The U.S. EPA Atlantic Ecology Division has prepared a State of the Region Report for Mid-Atlantic Estuaries to support the Philadelphia EPA Regional Office's goal of strengthening the knowledge of environmental condition to improve environmental management. Sources of information for this report included program reports generated by National Estuary Programs, Chesapeake Bay Program, the state monitoring programs in Delaware, Maryland, and Virginia, and federal programs such as National Status & Trends, National Shellfish Register, National Wetlands Inventory, and EMAP. The report starts with a description of the physical, chemical, and biological characteristics of the estuaries. The state of the estuarine environment then is summarized using a set of indicators for water and sediment quality, habitat change, condition of living resources, and aesthetic quality. Each indicator is briefly discussed relative to its importance in understanding estuarine condition; then its current condition is summarized. Finally, all of the information on the individual indicators is brought together for an overall evaluation of estuarine condition in the region. The usefulness of monitoring programs that collect consistent information with a well-defined sampling design cannot be overemphasized.

## **The Maryland Biological Stream Survey: A State Agency Program to Assess the Impact of Anthropogenic Stresses on Stream Habitat Quality and Biota**

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The Maryland Department of Natural Resources is conducting the Maryland Biological Stream Survey (MBSS), a probability-based, lattice design sampling program, stratified by river basin and stream order, to assess water quality, physical habitat, and biological conditions in first through third order, non-tidal streams. About 300 sites (75 m long) are being sampled during spring and summer each year. All 18 major basins will be sampled over a three-year period, 1995-97. MBSS developments in 1995-96 included (1) an electrofishing capture efficiency correction method (to improve the accuracy of fish population estimates), (2) two indices of biotic integrity (IBI) for fish assemblages (to identify degraded streams), and (3) land use information for catchments upstream of sampled sites (to investigate associations between stream condition and anthropogenic stresses). Based on fish IBI assessments at 270 stream sites in six river basins sampled in 1995, 11% of the stream miles were classified as severely degraded, 16% as degraded, and 6% as marginal. IBI scores declined with stream ANC and pH, a trend that was paralleled by other biological characteristics (species richness, biomass, abundance). Low IBI scores were associated with several measures of degraded physical habitat at the sampled sites, but not with local riparian buffer width. There was a significant negative association between IBI scores and urban land use upstream of sampled sites in the only extensively urbanized basin assessed in 1995. Future plans for the MBSS include (1) identifying all benthic macroinvertebrate samples to genus level, (2) improving and developing benthic macroinvertebrate, herpetofaunal, and physical habitat indicators, and (3) enhancing the analysis of stream condition-stressor associations by refining landscape metrics and using multivariate techniques.



## **Inventory of Environmental Monitoring Programs for the Mid-Atlantic Integrated Assessment (MAIA)**

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The U.S. EPA is working with federal, state, local and private partners to produce an interactive, spatial inventory of the environmental data in the mid-Atlantic. For each program, the inventory will display a map of sampling locations, a detailed list of variables measured, and design and administrative information. Users will be able to query the database to construct customized maps of programs that satisfy user-defined constraints. The inventory will contribute to a regional ecological assessment currently in preparation. It will also be used to design more integrated environmental monitoring and research activities. Its methods and format are currently being evaluated by the White House Committee on the Environment and Natural Resources (CENR) as a potential prototype for completing additional regions of the U.S. The inventory will be accessible on the Internet beginning in early FY97, and will be fully populated and capable of responding to user-defined queries by the end of the same year.

## **Integrated Monitoring and Assessment in the Mid-Atlantic Region**

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The objective of the proposed study is to assess and evaluate relations among the natural physical setting, environmental stressors, and chemical and biological conditions at site-specific, local, and regional scales within the Mid-Atlantic region. The effort represents a multi-agency integrated assessment based on complementary monitoring networks, science-based approaches, and research programs. The study primarily involves data assessment, conceptual model design, network evaluation, and regional and targeted assessments. Initial focus is on nutrients, sediment, and biota in aquatic systems, with emphasis in the Mid-Atlantic Highlands. The merging, compilation, and analysis of the multi-agency data will provide enhanced scientific understanding needed to support regionwide policies and decisions related to ecosystem management. In addition, the study provides a framework for additional stakeholders in the region, such as other Federal, State, and local agencies, as well as the scientific community in non-government organizations, academia, and private business, to enhance environmental research and monitoring of multiple resources across temporal and spatial scales.

## **A Framework for a Delaware Inland Bays Environmental Classification**

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Since Delaware's coastal bays have been highly eutrophied for at least 20 years and Maryland's coastal bays are not nutrient stressed, dominance of the fish community in Delaware's coastal bays by *Fundulus* sp. may be an indicator of nutrient stress. Maryland's coastal bays are menhaden, spot, and anchovy dominated. The dominance of *Fundulus* sp. in a nutrient-stressed system relates to the hardy nature of these fishes, especially in low oxygen conditions. Submerged aquatic vegetation (SAV) has been absent from the highly nutrient-stressed Delaware coastal bays for about 25 years. In contrast, SAV is still flourishing in Maryland's coastal bays. The loss of SAV as a habitat for young fish may also be contributing to the apparent species shift in Delaware's coastal bays. Indian River Bay is less hospitable to macroalgae (seaweeds) than Rehoboth Bay. Dominance of *Ulva* in Indian River Bay reflects its tolerance to varying salinities, higher nutrient levels, and increased turbidities, and indicates a stressed system. The total volume of macroalgae, especially in Rehoboth Bay, tends to follow the seasonal cycle for phosphorus. Based on an assessment of the ecological condition of the Delaware and Maryland Coastal Bays conducted by EMAP in 1993 and other related studies, the author offers a conceptual framework for Delaware's Inland Bays environmental classification considering the water quality parameters of turbidity, TSS, Chla, DIN, DIP, and O<sub>2</sub> as they relate to presence of SAV, seaweed abundance and diversity, benthic invertebrate diversity, and fish sensitivity to low oxygen.

## **Sustainability of Forest Ecosystems in the Mid-Atlantic Region**

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We will present an approach and results, if available, from currently developing analyses of the condition of the forest and related aquatic ecosystems in the Mid-Atlantic Region. This effort is part of a joint effort with the Environmental Protection Agency (EPA) and the USDA Forest Service and other partners, like North Carolina State University. Assessment questions linked to forest sustainability have been developed and will be presented. Part of the process of the Mid-Atlantic Integrated Assessment will involve stakeholders from a broad array of the forest community of interest in the review of assessment questions. The entire process will be guided by participation in the process by the stakeholder group. The analysis will include data from the Forest Health Monitoring Program, Forest Inventory and Analysis Program and other sources of relevant data. We will also include in the final analysis remotely sensed information and link it to ground-based data sources. Project completion is expected in early 1998.

## Assessing Ecological Sustainability Over Multiple Scales: A Landscape Indicators Approach

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Changes in the distribution and pattern of human populations and resulting changes in ecological resources (e.g., woodlands, rangelands, streams, and wetlands) at scales ranging from local communities to regions have had perhaps the most profound effect on ecological resource sustainability. These changes dramatically alter fundamental ecological processes, including the flows and balances of water, nutrients, energy, and biota, which in turn influence the condition and sustainability of desired ecological goods and services, including clean drinking water, flood-resistance watersheds, productive and healthy forests and agriculture communities, and diverse and abundant plant and animal life. A landscape analysis approach offers significant potential to assess the status and trends of ecological resources at multiple-scales across a relatively large region, and to relate such conditions to the presence of a range of anthropogenic and natural stressors. The landscape approach utilizes the latest in remote sensing imagery and computer-based, geographic information systems to calculate spatial indicators, such as forest fragmentation, human dominance in the landscape, and riparian ecosystem distribution. These spatial indicators or patterns can then be interpreted relative to the sustainability of environmental attributes valued by society. Because landscape analyses are spatially explicit, it is possible to determine how projected future changes in the landscape might affect the sustainability of ecological processes and associated goods and services that benefit society. Moreover, the approach permits an analysis of spatially-explicit, restoration options. We present preliminary results of a multi-scale landscape assessment for a 5-State area in the Mid-Atlantic Region of the eastern United States.

## How Does It Fit Together? Future Plans

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In the past, environmental decision making was not always driven by a thorough knowledge of baseline environmental conditions, nor were priorities focused as much upon solving specific ecological or systematic problems as they were with merely controlling emissions with equal vigor at all pipes and stacks. It's fair to say that pollution problems were so pervasive that almost any management strategy would have resulted in environmental improvements such as those witnessed over the past 25 years.

Regardless of the reasons for our successes, however, environmental problems are no longer as visible to the public as they once were, and the forces that sway public environmental policy are slowly receding. Now, more than ever, it is critical to demonstrate environmental improvements. Consequently, priority-setting and decision making must become more focused and "result based." This fact has been recognized by the National Academy of Public Administration (NAPA) in its April 1995 report on EPA, and has become manifest in Executive Order 12875 (National Performance Review), and in the Government Performance and Results Act of 1993.

Recognizing the need to base future environmental goals on a sound understanding of current environmental baseline conditions, EPA Region 3 embarked upon the development of a Mid Atlantic Environmental Data and Information Management System (EDIMS) in 1995. The goal was to develop an interactive computer system that could be used by staff and management alike to guide activities based upon an understanding of existing cause and effect relationships in defined geographic areas. A number of windows displaying both interpreted and actual raw data have been built into the Agency's Geographic Information System. Baseline maps can be pulled onto monitors at individual workstations to portray land use, demographics, monitoring locations, facility locations, and environmental conditions within EPA Region 3 ecoregions, estuaries, watersheds, State boundaries, counties, and census tracts. In addition, windows providing historic air, water, and waste data sets that correspond to specific monitoring locations in the defined geographic areas can be displayed to provide hard information regarding the condition of the resources being geographically displayed. EMAP data gathered and interpreted through the Mid-Atlantic Highlands Assessment (MAHA) has played an integral role in the development of this system. When the system is completed, over 400 data sets will have been built into an interactive database, which can be used by Region 3 managers and staff (and eventually the public) to plan and manage for environmental results.

## Introduction to R-EMAP Strategy

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The R-EMAP program is a partnership between the EPA Regions and ORD to evaluate and improve the EMAP approach in a manner directly applicable to resource managers. The goals for the program are: 1) to assist in incorporating the latest science on ecological monitoring into the EPA Regional, State, Tribal and local decision-making process, and 2) to advance the science of ecological monitoring as a tool for problem formulation in risk assessments and measuring the ecological results of risk management actions. The criteria for selecting R-EMAP projects are: 1) they address real environmental issues where monitoring results will influence decisions, 2) they advance the state of science of ecological monitoring, 3) they incorporate good scientific practices as evidenced by an acceptable peer review, and 4) they support the development of the EMAP/CENR approach to environmental monitoring. R-EMAP projects offer opportunities to obtain numerous small-scale experiences in ecological monitoring across wide biogeographic and political boundaries as a complement to the larger scale EMAP efforts. They also can provide initial opportunities to develop and test indicators across diverse environmental conditions. R-EMAP studies were initiated in 1993/1994 in all 10 of the EPA Regions. A brief description of the studies currently being completed and those to be initiated in 1997 will be presented.

## **Relationships Between Riparian Conditions, Stream Habitat, and Fish Assemblages in Great Plains Streams**

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We describe physical environment assessment parameters derived from a probabilistic sampling design (R-EMAP) and fish assemblage parameters for wadeable streams (approx. 300) in the mid-latitude Great Plains (Kansas, Missouri, and Nebraska). Data were collected during a summer index period in 1994 and 1995. We describe how these parameters vary across the Plains from the sub-humid eastern edge to the semi-arid western areas. We compare the observational data with water quality criteria for the various streams, describe habitat impairment, and describe correlations between habitat parameters and fish assemblages. We describe the development and application of a multimetric index of biotic integrity (IBI) to make regional assessments of ecological condition. Candidate metrics (various measures of taxonomic richness, abundance, and guild structure) were devised based on their applicability to regional ichthyofauna, and on their hypothesized response to various types of human disturbance. We defined reference condition based on historical and current information. Hypothesized responses of individual metrics were confirmed using independent measures of riparian and instream habitat disturbance (physical and chemical). We examined redundancy among metrics and quantified important spatial and temporal variance components of metrics and the IBI. Threshold IBI scores associated with various categories of impairment were developed and applied.



## Mercury Contamination in Maine Lakes

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Maine's R-EMAP study, Fish Tissue Contamination in the State of Maine, was conducted in 1993-4. The goals of the study were to 1. determine the distribution of selected contaminants in fish from Maine lakes, 2. determine risk to human and wildlife consumers of fish from Maine lakes, 3. identify factors that affect the distribution of contaminants in fish tissue to gather evidence relating to likely stressors and provide insights useful in managing any problems determined, and 4. expand and compare a more intensive sampling protocol to that of EPA's national EMAP program in order to determine the most efficient and optimal design. Results showed elevated concentrations of mercury in fish all over Maine, which caused issuance of a fish consumption advisory for all lakes and ponds in the state in May 1994. Concentrations of mercury, DDT, and PCB in some samples exceed critical levels for wildlife consumers. Fish factors (species, age, length), lake water quality factors (color and sulfate), and lake morphometric factors (watershed area to lake area ratio and lake elevation) were important, in order of decreasing importance, in determining mercury concentrations in fish. Geographic stressors were relatively unimportant in explaining variation in contaminant concentrations. R-EMAP resulted in higher estimated risk to human and wildlife consumers of fish contaminated with mercury but a lower risk from chlordane than did EMAP and seems to provide more accurate data for state or regional management decisions.

## **Evaluation of R-EMAP Techniques for the Measurement of the Ecological Integrity of Streams in Washington State's Coast Range Ecoregion and Yakima River Basin**

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We used methods from EPA's Environmental Monitoring and Assessment Program (EMAP) to assess the status of streams on a regional basis within the Yakima River Basin and Coast Range ecoregion of Washington State. Stream condition was assessed using EMAP indicators for habitat (chemical and physical) and biology (invertebrate and vertebrate assemblages). Site locations were chosen using a probability-based process. The study objectives were to determine the ecological condition of wadable, 1st-order through 3rd-order streams; to determine relationships between the ecological condition of these streams and land uses; to provide information for the development of water quality biological criteria; and to determine the applicability of EMAP derived methods in Washington. Multivariate statistical techniques were used to evaluate a stream classification which used ecoregion, stream size, and geomorphology. We evaluated seasonal and interannual precision of habitat and biological metrics by repeat sampling (up to 4 visits each) among seven sites. Relationships between habitat variables and biological variables were used to determine instream quality and ecological relationships.

## Temporal Change in Sediment Quality of the New York Harbor Area

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A two-year Regional Environmental Assessment and Monitoring Program (R-EMAP) of the surficial sediments and benthos of the Harbor, New York Bight Apex, and western Long Island Sound was conducted to better understand the spatial extent and biological significance of toxicants and other sedimentary stressors. Previous studies document abnormal benthic assemblages, chemical contamination of sediments, and other environmental stressors in parts of this study area. A stratified random design was used to sample sediment chemistry, toxicology and benthic macrofauna synoptically, permitting estimates of sediment quality with known confidence for each of six strata within the study area. Synoptic measurements were made at 168 stations of: chemical concentrations in sediments, sediment toxicity assays, and the structure of benthic macroinvertebrate assemblages. Benthic invertebrate structure was assessed with traditional methods, and with multivariate indices. One index was adapted, validated and recommended as optimal for regional managerial uses. Essentially all pre-1993 benthic data were purposively sampled from only portions of the Harbor, inducing uncertain biases into temporal or spatial comparisons. Despite these biases, several major historical changes in sediment quality are evident. Principal departures from historically "normal" sediment quality took place before the 1950s; by some measures, sediment quality was degraded much earlier.

## **Linking Monitoring and Cause-and-Effect Research: EMAP's Index Site Demonstration (DISPro)**

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The EMAP program has been organized into three primary elements: Multi-Tier Design, Indicators, and Index Sites. The Index Sites program (DISPro--Demonstration Intensive Sites Project) is the primary activity with the Index Sites element of EMAP. This project represents an inter-agency effort between EPA/ORD and DOI/NPS to develop a demonstration of an intensive site network of monitoring and research locations throughout the United States utilizing the Nation's parklands and "outdoor laboratories." Twelve parks were selected to establish this demonstration. The criteria for the selection of these 12 parks are somewhat ambiguous with the exception that all 12 parks are readily accessible, have a history of monitoring environmental information, and represent a broad spectrum of ecological communities. EMAP, through DISPro, is examining whether a "network" of sites existing within the parks can be used to address monitoring issues for global-scale environmental stressors (e.g., air deposition) as well as locale-specific stressors (e.g., air deposition, water-borne) and coordinated with cause-effect, issue-based research related to these environmental stressors. As a first activity, EPA will provide each of the sites with the instrumentation to monitor UV-B. The intent of the program is to initiate a consistent air monitoring program at each site to be followed by consistent monitoring within other media. In order to demonstrate the relevancy of this monitoring, the project will initiate research projects at all of the sites (eventually) to examine the effects of environmental stressors of importance at each of the sites.

## Macrophage Aggregates: Taking Field Hypotheses Back to the Laboratory

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Macrophage aggregates (MAs) are histologic structures found in kidney, spleen and sometimes liver of fishes. They are involved in the specific immune response, functioning as primitive lymph nodes, but also serve as repositories for both endogenous and exogenous waste products. Numerous field studies have found increased numbers or size of MAs in fishes from contaminated sites. Monitoring programs, including EMAP, USGS's BEST and NAWQA programs, and NOAA's Status and Trend Program have or are using these structures as indicators of contaminant effects on fish. However, there is little experimental data to validate their use as a biomarker or to increase our understanding of the processes that lead to their increase in number or size in fish from contaminated sites. A series of laboratory dietary exposures of striped bass to sublethal, graded levels of arsenic, dieldrin, arsenic and dieldrin combination and nickel were conducted over a two year period. A number of immune function assays, nonspecific disease resistance factors, and fish health assessment methods were measured in conjunction with MA parameters. We found MAs more amenable to field collections; changes in size and number more easily correlated with contaminant exposure; and that they are less affected by collection method, temperature, etc. than are immune function assays.

## Determining the Cause of Benthic Condition

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A benthic index for northern Gulf of Mexico estuaries has been developed and successfully validated by the Environmental Monitoring and Assessment Program (EMAP) in the Louisianian Province. The benthic index is a useful and valid indicator of estuarine condition that is intended to provide environmental managers with a simple tool for assessing the health of benthic macroinvertebrate communities. EMAP also measures indicators of adverse sediment, habitat, and/or water quality that may have detrimental effects on the health of benthic communities. Associations between the benthic index and indicators of hypoxia, sediment contamination, and sediment toxicity were investigated to determine the cause(s) of degraded benthic condition. The results showed that, on a local scale, the associations between the benthic index and potential environmental causes were not always clear. In Penscala Bay, FL, for example, there was a significant correlation between the levels of toxic chemicals (e.g., DDT, cadmium, and lead) in the sediment and the benthic index, especially in the bayous which have known contamination problems. In Corpus Christi Bay, TX, however, there was a significant correlation between the benthic index and sediment contaminants in the main shipping channel, but a large area of impacted benthic communities was not associated with contaminants, toxicity, or hypoxia. Nevertheless, a benthic index is a valuable tool for identifying areas of potential degradation and tracking the status of environmental condition in large geographical regions.

## Linking Rates and Effects of Acidic Deposition Through Intensive Monitoring and Regional Interpretation

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Acidic deposition is a regional phenomenon, but its effects have traditionally been studied using site-specific, intensive monitoring. We present trends information for 38 lakes of high-to-moderate acid sensitivity (defined as acid neutralizing capacity [ANC] < 100  $\mu\text{eq.L}^{-1}$ ), and 15 deposition monitoring stations, in the northeastern U.S. for the period 1982-1994. Trends at each site were assessed through use of the Seasonal Kendall tau test; the resulting statistics were combined, through a technique analogous to analysis of variance, to produce quasi-regional estimates of change for key chemical variables. Rates of sulfur deposition declined significantly across all of the northeastern region during this time period, while rates of nitrate and ammonium deposition were unchanged. While all lakes exhibited strong decreases in sulfate concentrations ( $\text{DSO}_4^{2-} = -1.8 \mu\text{eq.L}^{-1}\text{yr}^{-1}$ ,  $p < 0.001$ ) in response to declining S deposition, there was a strong contrast in the response of acid/base status between lakes in New England and lakes in the Adirondacks. As a group, the New England lakes exhibited recovery ( $\text{DANC} = +0.8 \mu\text{eq.L}^{-1}\text{yr}^{-1}$ ,  $p < 0.001$ ), while the Adirondack lakes exhibited either no trend or further acidification (as a group,  $\text{DANC} = -0.3 \mu\text{eq.L}^{-1}\text{yr}^{-1}$ ,  $p < 0.05$ ). This contrast can be attributed to changes in base cation concentrations: New England lakes exhibited base cations declines that were smaller in magnitude than declines in sulfate, producing the observed recovery in ANC; Adirondack lakes showed base cation declines that were very similar to those of sulfate, and no recovery was evident.

## **Do AVS Analyses Add to Monitoring and Assessment Programs?**

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Incorporation of acid volatile sulfide (AVS) into the suite of parameters included in sediment monitoring programs has evolved in response to increasing acceptance of the following hypothesis: AVS analysis is widely applicable in quantifying the binding capacity of sediments for metals forming relatively insoluble sulfides (i.e., Cd, Cu, Ni, Pb and Zn) and, when coupled with results of analyses performed on simultaneously extracted metals (SEM), allows for the prediction of concentrations below which no biological effects should be seen and above which effects may be seen. Results of laboratory experiments by us and other researchers indicate that AVS does not consistently quantify metal binding capacity of sediments. In addition, recent EMAP results demonstrate that AVS analyses, when coupled with SEM analyses, do not provide a useful basis for the prediction of potential effects/no effects of metal concentrations in sediments. Although AVS provides useful information on the geochemistry of sediments and may be useful in establishing remediation strategies in highly contaminated systems, its limited use in monitoring programs may not justify its inclusion. Also when AVS results are coupled with SEM data, erroneous conclusions may be drawn.



## **Linking Environmental Stressors and Responses: Intensive Monitoring and Research**

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Answering scientific questions about new environmental issues often requires multiple sampling and analytical approaches applied at diverse time scales, and in unpredictable ways. Three aspects are discussed in this context using a water quality issue (hypoxia) in the northern Gulf of Mexico continental shelf: (1) the usefulness and limitations of fixed station sampling in comparison to process-based sampling; (2) alternative methodologies to expand temporal coverage to include pre-monitoring conditions, especially retrospective analyses, and, (3) decadal-long and rigid sampling schedules and methodologies that are supplemented with add-ons and special efforts, including studies of chaotic or random events. Limited funding for cruises requires a strong sampling design stage and diverse approaches. What has worked in the Hubbard Brook ecosystem studies also works offshore: to provide a stable funding instrument; flexibly find ways to enroll diverse and innovative talents of both independent thinkers and creative scientists who can work together; and to take risks.

## **An Emergy Analysis of Human Carrying Capacity and Sustainability for Maine**

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The human carrying capacity for a region at a specified standard of living depends on the economic and environmental resources of the region and the exchange of resources across regional boundaries. The length of time that a human population living at a given standard can be sustained depends on the time over which the necessary resources are available. All environmental, economic, and social resources are produced by energy transformations; therefore, the energy required for their production can be specified and evaluated in common terms by converting their energy values into emergy. Emergy is defined as all the energy required both directly and indirectly to make a product or service expressed in equivalent units e.g., solar equivalent joules. Emergy values and indices are used to evaluate the resource base for Maine, a politically defined region, and to define the standard of living and human carrying capacity for the 1980 and possible future resource bases. Emergy use in Maine is heavily subsidized by fossil fuels from outside the state. The 1980 standard of living for Maine people exceeded the national average as measured by fuel, electricity, and emergy use per person. If fuel emergy inflows relative to renewable emergy sources increases to the average ratio for the U.S. in 1983, the population living at 1980 standards could increase to 2.3 million or twice Maine's 1980 population. In contrast, the carrying capacity for Maine at the 1980 standard of living based on Maine's renewable resources alone was 0.29 million or 26% of the 1980 population.

## Quantifying the Myth of Sustainable Development

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The concept of "sustainable development" certainly sounds attractive--in this world we can have our cake and eat it too. We examine quantitatively some indices of sustainable development in the United States, Costa Rica, Mexico, and South Korea: first by identifying the environmental impacts associated with the birth of each new individual and projecting that impact over time, second by examining some general trends in total pollutant production, and third by calculating energy and agricultural efficiency over time. We find that many indices of "increased sustainability" have been misleading, and that there is little or no indication that we are becoming any more "sustainable" or efficient. Specifically: all four nations are increasing total energy and material use, and there has been little or no increase in aggregate energy or material efficiency except for that associated with use of higher quality resources or reduced demand; while there has been much reduction of specific pollutants in the United States, much of this has been due to the export of the most polluting industries; efficiency improvements in the end use of resources has been compensated in part by depletion in the extractive sectors and by effects of overall increase in demand. We conclude by suggesting that continued population and economic growth in each country are likely to make the achievement of any kind of "sustainability" increasingly challenging. Sustainability, if that is desirable, requires a very different approach than what we have undertaken to date.

## The Ecological Footprint: An Indicator of Progress Toward Sustainability

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Sustainability means to secure people's quality of life within the carrying capacity of nature. To make sustainability work, we need indicators of progress toward that condition. We require indicators that tell us whether our economic activities are within the carrying capacity of the biosphere. People live inseparably from ecosystems. They depend on the steady supply of the basic requirements for life--food, water, energy, fibers, waste sinks, and life-support services--that ecosystems supply. The "Ecological Footprint" approach allows us to quantify the human use of nature as compared to nature's carrying capacity. It does this by estimating the total biologically productive area necessary to provide a given population with its resource supplies and to absorb its waste, using prevailing technology. Thereby, it summarizes people's "ecological impacts" and provides an indicator of sustainability. This paper explains the mechanics of a recent and more complete footprint calculation method for nations and regions. As the method is standardized, the relative ecological load imposed by nations and regions can be compared. Further, a nation's or region's consumption can be contrasted with its local ecological production, providing an indicator of potential vulnerability and contribution to ecological decline. These footprint calculations not only become the starting point for more detailed local analyses and time series, they can also be used for progress monitoring, equity appraisals (through the measurement of the footprint distribution within a population), technology and policy assessments, or eco-labelling. Such examinations can give direction for local, national, and global efforts, and make the concept an effective planning tool and a guidepost for a more secure, equitable, and sustainable future.

## Studies on the Population Genetics of Endemic Teleosts from Selected Watersheds

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A goal of conservation genetics is to estimate the level and distribution of genetic diversity for populations of a species. This information is required under the assumption that genetic variation enhances a populations probability of survival and preserves evolutionary processes, especially for those species faced with exposure to environmental stressors. Molecular approaches are particularly useful for measuring diversity within and among wild populations where no sequence data is available. We employ Random Amplified Polymorphic DNA (RAPD) analysis to generate genetic profiles that when coupled with improved statistical treatments are used to develop indices of similarity within and among fish populations. The RAPD method is a much less costly, complex and labor intensive procedure than other techniques employed. The RAPD method provides an arbitrary sample across the genome and can generate a virtually unlimited number of loci and therefore a robust data set for use in genetic analysis, making it well suited for use in evaluating the vulnerability of populations to stressor exposure. We have used the RAPD technique to assess the level of genetic diversity within and among populations of fish from impacted and reference sites across a wide geographic range. These types of measurements, in the absence of extensive population natural histories or evaluations, when made against reference populations can identify trends in specific populations as well as across large geographic areas, thus providing a yard stick by which to assess the vulnerability of a region to the impact of stressors. It is hoped that this level of information will aid in making informed decisions on resource management.

## **Genetic Impact of Low Dose Radiation on Human and Non-Human Biota in Chernobyl, Ukraine**

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The accident at the Chernobyl nuclear power plant resulted in the release of radioactive material into the natural environment and accordingly radiation overexposure of human and non-human biota in affected regions. The chromosome aberrations level was used as the main test-system for evaluating the radiation-induced genetic impacts. The cytogenetic data obtained on animal and plant species from the contaminated areas were reviewed. The increased level of chromosome damage mostly depending on dose or dose rate has been found in all species investigated. The chromosome aberrations investigations in evacuees from the town of Pripjat' and in liquidators were carried out and the sufficient increasing of aberration yields in subjects investigated has been shown. These data have been used for biological dose reconstruction in early post-irradiation periods, and the comparison between biological and physical dose estimates has been performed. The 10-year follow-up studies showed the complex dynamics of the genetic effects in the different excessively irradiated human cohorts. The increased chromosome sensitivity to natural environment mutagens seems to be the common late end-point in human and non-human biota irradiated in the Chernobyl area. New approaches using fluorescence in situ hybridization (FISH) technique have been employed for obtaining the information about the real degree of genetic damages in humans in longer periods after the accident. The positive correlation between early and late cytogenetic effects has been found.

## **Impacts of Environmental Pollutants on Genetic Diversity of Marine and Estuarine Organisms**

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Contaminants may cause both short-term and long-term genetic alterations in organisms and populations. Yet, a synthetic view of these changes is lacking. Short-term effects include decreased reproductive success, carcinogenesis, and metabolic alterations. Long-term, multigenerational changes may be caused by direct DNA damage (mutations) or indirect effects attributable to natural selection. Recently, molecular techniques permit new approaches for examining long-term effects. An overview of methods available to assess short-term and long-term changes in organisms in situ will be provided, with emphasis on the most useful tools for monitoring. In addition, some techniques provide discrimination of stressor types. For example, sea urchin embryos, a common subject of toxicologic monitoring, have been used to elucidate effects of increasing ultraviolet-B as a consequence of ozone depletion as well as to examine effects of chemical contaminants. Potential approaches for fingerprinting effects of classes toxic substances include biomarker-based toxicity identification evaluation and analysis of unique molecular changes.

***EMAP Symposium Short Talks***



## **Relating Coastal Development to Living Marine Resources and their Habitats**

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Coastal ecosystems receive virtually all of the water flowing off the continental United States. As the human population increases, so do waste loads and use of the landed surface. Changes in land use result in change in land cover, which affects water quality, and subsequently, coastal and estuarine habitats, and their living resources. Lack of understanding of the cumulative effects of land cover and changes in land cover on these habitats and their resources, has limited appropriate management of landscape activities. Additionally, in the U.S., as elsewhere in the world, human population in the coastal region is increasing at an ever quickening pace. Our ability to monitor resultant land cover and habitat change has not kept pace with the change, and management performance has been more reactive than proactive. To address these issues, the NOAA has undertaken a program, the Coastal Change Analysis Program (C-CAP), to monitor the coastal region of the U.S. on a one to five year repetitive basis. The goal is to develop a digital data base of land cover and habitat change in the coastal region of the U.S. that, when integrated with other data within a GIS, ultimately will enable the modeling and analysis of linkages between development in the coastal region and ecological and economic productivity of coastal and estuarine habitats and their living marine resources. Early results along with implications for living marine resources will be presented.

## Development of an Environmental Stress Index Using Parasites of Fish

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During the 1994/1995 EMAP-Estuarines program in the Carolinian Province, we investigated the feasibility of developing an environmental stress index using parasites of fish as response indicators. Parasites of fish are an indigenous component of healthy ecosystems. Within the EMAP-E design, the suite of environmental parameters which may affect parasite abundance, richness, prevalence, and diversity can be divided into three categories: 1) the physical and chemical characteristics of the water and sediment (including contaminants) external to the fish; 2) the internal environment defined by the physical condition (physiological) of individual fish; and 3) the presence and relative abundance of benthic macroinvertebrates, many of which serve as intermediate hosts. The biotic response of parasites to environmental stressors is also reflected in the health of fish. Parasite assemblages of silver perch *Bairdiella chrysura* respond to both natural and anthropogenic stressors. Specific parasites can respond to particular environmental stressors. Some parasite/stressor pairings include: monogeneans and temperature; crustacea and a mixture of salinity, metal and organic contaminants; nematodes and contaminants; and protists and low dissolved oxygen. Parasites of fish may be more sensitive to environmental stressors than are the fish themselves. A parasite index was developed using the parasite indicator responses to selected environmental stressors. Other indices developed using EMAP-E data including the habitat/exposure index, metal and organic contaminant indices, and an infauna index were used together with the parasite index to develop an environmental stress index. The environmental stress index discriminates between polluted and unpolluted sites. Development of the environmental stress index using parasites of fish has relevant application to fisheries management and coastal monitoring programs.

## Semipermeable Membrane Devices as Universal Sentinel Pseudo-organisms

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Recent advances in the design of semipermeable membrane devices (SPMDs) have made a broad range of interesting applications possible. A promising design by J.N. Huckins, et al uses a thin walled polyethylene tubing enclosing a film of high molecular weight lipid. Lipophilic compounds adsorb on the polyethylene surface, permeate through microscopic transport "corridors" in the membrane, and concentrate in the lipid solvent. Potentially high concentration factors are possible for such hydrophobic contaminants as PCBs and polyaromatic hydrocarbons (PAHs). Since SPMDs lack such complications as biotransformation, metabolism, limited viability, etc., inherent in "bioextraction" or biomonitoring approaches to surveying the environment for trace organic contaminants, the SPMD represents a possible universal sentinel device. We report results comparing the accumulation of PAHs in SPMDs to traditional biomonitors such as bivalves in the field and laboratory. Results for PAH accumulation by oysters and SPMDs exposed to 34 PAHs in laboratory flow-through studies at the nominal concentrations of 10 ppt, 100 ppt, 250 ppt in seawater will be detailed. Practical concerns such as ease of use, ease of analysis, reproducibility, etc., further demonstrate the superiority of SPMDs. These data and these properties of SPMDs suggest SPMDs represent universal sentinel "pseudo-organisms" and can provide a standard method and measure of aquatic contamination on local as well as global scales. We gratefully acknowledge the support of the EPA-EMAP and the American Petroleum Institute Biomonitoring Task Force.

## Seed Clam Growth: A Sediment Bioassay Developed in the Carolinian Province

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A new sediment bioassay was developed in conjunction with EMAP studies conducted in the Carolinian Province using juvenile seed clams, *Mercenaria mercenaria*. The assay is a sublethal assay, based on growth (total dry weight) after a 7 day incubation period. Seed clam assays were significantly more sensitive than amphipod acute toxicity assays. Optimization components include use of hatchery-reared juvenile clams in a rapid growth phase, and size-sieving to insure a similar size range. Juvenile clam growth was not affected by sediment type, i.e., clams grew well in muddy and sandy sediments. They were slightly more sensitive to ammonia than amphipods (NOEC total ammonia 14-16 mg/L). Ammonia concentrations above these levels were relatively rare and more common in reference sites, so most of the false positives could be explained by ammonia toxicity. This assay possesses a number of other positive attributes that are desirable for a bioassay, including the requirement for a relatively small sample size (500 ml), minimal time and effort, balanced sensitivity, low incremental costs, and high information gained. The seed clam assay is believed to be a valuable tool for EMAP as well as other monitoring efforts for estimating potential chronic toxicity.

## **Benthic Biological Processes and Eh as a Basis for a Benthic Index**

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It is proposed that the EMAP benthic index (BI) for estuarine condition, used for characterizing benthic structure, can be facilitated with a routine, effective, and affordable vertical Eh profile through the benthic bioturbation zone as a reconnaissance tool much like the REMOTS(R) camera. Benthic biota, in the course of feeding, ventilation and habitat development, ingest and transport particle-borne contaminants and irrigate anoxic-hypoxic sediment. Specific activities include irrigating burrows with overlying seawater; burrowing through and breaking up cohesive sediment; deposit and suspension feeding, digesting, pelletizing and transporting feces and pseudofeces; and developing habitat structures. Collectively, these processes advect particles and seawater between bottom water and deep sediment. Such advection creates a full spectrum of biogeochemical conditions of solubility, reactivity, and microbial metabolism, and results in remineralization of excess carbon and organic contamination, facilitates dissolution of most trace metals, and pushes the vertical Eh profile toward oxidizing conditions. It is proposed that a standard Eh probe be inserted into grabs, box cores or gravity cores, at 1 cm intervals downward to below the bioturbation zone. The vertical profile and the deep baseline then would express the scope of advection and metabolism by the macro, meio and microbenthic community.

**Benthic Infauna in the Florida Portion of the Carolinian Province: Relating  
Community Structure to Environmental Variables Using Nonmetric  
Multidimensional Scaling and Similarity Analysis**

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Nineteen stations were sampled with two replicate Young grabs in each of two years (1994-95) in association with the EMAP-Estuaries Carolinian Province Base Monitoring in Florida. A total of 295 and 197 unique benthic infauna taxa were enumerated in 1994 and 1995, respectively. Environmental data (bottom water quality, sediment grain-size, sediment metals and organics) and benthic community data were analyzed using hierarchical agglomerative cluster analysis and ordination via nonmetric multidimensional scaling. Bray-Curtis similarities were used as the distance measure. Multivariate analyses were complemented by examining incremental contributions of environmental variables and benthic taxa to similarity values using a percentage similarity technique. In both 1994 and 1995, low-salinity sites in tributaries to the St. Johns River had benthic communities dramatically different from those of moderate-to-high salinity sites. Low-salinity sites were characterized by taxa such as the tubificid oligochaete, *Limnodrilus hoffmeisteri*, the gastropod *Littoridinops monroensis*, and the bivalve *Mytilopsis leucophaeata*. Given similar salinities, sites with high silt-clay fractions generally had much lower species diversity. Slight species shifts in association with latitudinal gradients and concentrations of sediment metals and organics were apparent, but physical factors, notably salinity and silt-clay fraction, were the primary correlates with benthic community structure.

## Estuarine Benthic Macroinfaunal Species Variables for Use in Regional Assessments

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Although individual "indicator species" approaches are of limited use in regional assessments, the proportions of pollution sensitive or tolerant species is often useful across habitat boundaries. To identify estuarine "indicator species," we quantified the relative affinity of benthic species for pollution stressed and relatively unstressed sites in 41 estuarine systems from Cape Cod to Chesapeake Bay. Stressed and unstressed site definitions were based on sediment contaminant and organic carbon concentrations, and bottom water dissolved oxygen. Benthic species abundance proportions were tested for differences among 226 stressed and 130 unstressed sites using the nonparametric Wilcoxon rank sum test. In order to minimize confounding pollution responses with responses to natural environmental differences, separate comparisons were performed for eight salinity-substrate habitats. We identified forty-three taxa, thirty-one of which were relatively common, as indicators of unstressed conditions, but only one good indicator species for stressed conditions. Nine of the forty-three indicators of unstressed conditions were significant in multiple habitats. The indicator of stressed conditions was the polychaete worm *Streblospio benedicti*, and was significantly more abundant at stressed sites in five of the eight habitats. Similar approaches may be useful in other habitats, such as freshwater streams or plankton communities, for identifying "indicator species" variables useful in regional assessments.

## **Virginian Province Macroinfaunal Community Structure: PCA-H Analyses and an Assessment of Pollution Degradation Indices**

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We evaluated the three major EMAP-E Virginian Province benthic degradation indices and used multivariate analyses to describe the major patterns in Virginian Province benthic community structure. Ordination and cluster analysis based on the CNESS faunal distance metric showed that the dominant factor controlling Virginian Province community structure is salinity. Benthic degradation indices must either control for salinity, or should be based on components of community structure that are independent of salinity. The EMAP-E VP degradation indices cannot be considered adequate. There may be no single index that could identify degraded benthic communities across the array of habitat types encountered in EMAP-scale sampling. However, as May noted in 1975, natural Virginian Province benthic communities tend to follow the log-series distribution of individuals among species. Disturbed benthic communities depart radically from log-series expectations. This pattern appears worldwide and at most depths.



## **Common Properties of Arid and Aquatic Ecosystems Under Stress**

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A comparison of the response of semi-arid grasslands and aquatic ecosystems to a suite of anthropogenic stresses reveals common structural and functional responses. These include alterations in nutrient cycling, progressive dominance by opportunistic and non-native species, and loss of substrate stability. These features point to key indicators by which to assess ecosystem degradation resulting from a variety of stress pressures. The resulting modification of the availability of essential resources, degradation of basic substrate and pre-empting of native species by exotic and/or non-local species renders restoration or rehabilitation of stress-altered ecosystems highly problematic.

## **Long-Term Changes in Nitrogen in Surface Water: Deposition or Forest Disturbance?**

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Aggrading forest ecosystems in the eastern U.S. typically retain nitrogen (N) for at least 150-200 years, losing less than 5% of the total mineralized N to stream water. Therefore, accelerated losses of N from these systems must be due to some external factor, such as the following three that have been proposed: (1) pre-mature N saturation, due to excessive additions of N from atmospheric deposition; (2) deforestation; or (3) climatic anomalies. In this paper, we provide evidence for a fourth mode of N leakage from forest ecosystems: defoliation by herbivorous insects. Using data from watersheds in the mid-Appalachian region, we demonstrate the regional-scale effects of defoliation by the gypsy moth larva on N fluxes to surface waters and on acid-base chemistry. In addition, our analysis suggests that observed changes in both nitrate and base cation concentrations at the Hubbard Brook Experimental Forest may be partly explained by documented forest defoliations in the 30+ year historical record which have seemingly been ignored. Forest disturbances are also shown to hamper the establishment of a direct relationship between long-term changes in deposition of both sulfur (S) and N and surface water acid neutralizing capacity (ANC) which is needed to verify any improvements in acid-base status brought about by the Clean Air Act Amendments of 1990.

## **Changes in Fish Diversity as an Early Warning of Forest Decline**

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Sulfate, nitrogen and hydrogen ion deposition in the Laurel Hill region of the Appalachian Plateaus Province in Pennsylvania has been very high. Records indicate that losses of fish first occurred about 1960, although unrecorded losses probably preceded that date. Research has attributed fish loss in this region to chronic and episodic stream acidification. Relatively recently, mortality of northern red oak has become a problem in parts of the region with mortalities as high as 60 percent of standing trees evident in some areas. Preliminary analysis indicates that soil acidification may play a significant role in the observed mortality. If this is the case, it would appear that fish losses in the region were evident at least 25-30 years prior to the current decline of northern red oak. Therefore, changes in fish diversity caused by acidification may be a prelude to more widespread ecosystem damage as a consequence of chronic deposition of acidifying elements.

## **Changes in Forest Integrity at Anthropogenic Edges**

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Edge effects on forest integrity were assessed by examining microepiphytes (bark-dwelling lichens and bryophytes), vascular plants and light levels in transects from the anthropogenic edge, 45 m into the interior, in 3 forest types: hardwoods in NJ and NY c. 50 mi from NYC and hardwood and red pine and jack pine in northwest Minnesota, and in control forests without edges. Divergent findings from different forest types and edge types show that generalizations are elusive and that indices of integrity must be customized to the forest type. Enrichment of epiphyte diversity at edges was seen in only two of seven site/tree combinations, both sites having long-established edges at which trees had produced dense growth of lower branches. Species richness alone may be a misleading proxy for forest integrity. For both lichens and plants, species added at the edge are not those of the forest interior. Thus assessments of forest integrity require an understanding of individual species ecology. Forests with an anthropogenic edge supported lower lichen diversity, even 45 m from the edge, than intact forests, an effect not explained by light levels. In the eastern forests the effects of air pollution swamp lichen distribution patterns, reducing their potential for detecting other aspects of forest integrity.

## **Spatial Patterns of Land-use and Land-cover in Stream Buffers and Whole Watersheds Related to an Index of Biotic Integrity for Fish Assemblages of Urban Streams**

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Watersheds that experience rapid urbanization in the Metropolitan Atlanta area undergo landscape transformations from two initial land-use and land-cover conditions - either forested and little agricultural land use, or having up to 20 percent pasture, mainly used for poultry or dairy production. For eight third- or fourth-order streams, near-stream land-use and land-cover patterns (in 50 meter incremental buffers ranging from 50 to 500 meters) were analyzed and compared with whole watershed land-use and land-cover, and related to fish-assemblage data. Land-use and land-cover data from 1993 aerial photography and 1990 landsat Thematic Mapper imagery were used in the study. Four streams had varying degrees of urban land use. An Index of Biotic Integrity (IBI) was calculated from fish assemblage data collected during 1993 and 1994. IBI scores ranged from 37 in a forested stream to 13 in an urban stream. In urban watersheds, forest cover within the first 50-meter buffer (riparian area) was on average 20 percent greater than in the whole watershed. However, regression analysis indicated that correlations between IBI scores and percent forest cover within 50 meters of streams or whole watersheds were similar ( $r^2=0.63$  and  $0.59$ , respectively). This study indicates that restoration of urban watersheds should consider land-use and land-cover of the whole watershed in addition to that of riparian areas.

## **Associations Between Landscape Pattern and Water Quality: Mid-Atlantic Region**

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Measures of landscape pattern are useful to monitor change and assess the risks it poses to ecological resources. Streams and rivers serve as integrators of terrestrial landscape characteristics. Many studies have shown that the proportion of different land uses within a watershed can account for some of the variability in surface water chemistry. We are evaluating associations between both land use pattern and proportion and water chemistry (nitrogen, phosphorus, conductivity, and residue) for the Mid-Atlantic Region of the United States. The purpose is to characterize the vulnerability of watersheds to nonpoint-source water pollutants for regional assessment activities in the region. The initial analysis uses Advanced Very High Resolution Radiometry (1 km) satellite imagery and seven land cover classes. Watersheds ranging in size from 900 to 6,500 sq km are the analysis units; these are the Cataloging Units of the U.S. Hydrologic Units. Canonical correlation analysis provides an integrated multivariate approach. Both land cover proportion and pattern are associated with the chemistry parameters. Nitrogen is most highly correlated with the chemistry canonical variable followed by residue. Proportion of forest is most highly correlated with the landscape canonical variable followed by either disturbed edge or shape complexity.

<sup>1</sup> Research sponsored jointly by the U.S. Environmental Protection Agency, Office of Research and Development, under Interagency Agreement DW89937287-01-2 under Lockheed Martin Energy Research Corp. for the U.S. Department of Energy under contract number DE-AC05-96OR22464.

## **Regional Patterns of Summer Declines Among Large Daphnids in the Conterminous U.S.**

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A regional pattern of cladoceran body size and midsummer decline/disappearance duration was detected from a review of previous studies (34 water bodies). In lakes with fairly cool summer temperatures, all *Daphnia* species were relatively large and at least one daphnid species persisted through the summer. In water bodies in which water temperatures were warmer, large daphnids declined markedly or disappeared for most of the summer. At higher summer temperatures, daphnid sizes ranged from medium to small, and daphnids tended to be absent from the plankton during the summer. Daphnids were generally rare in Florida, and the abundance of small daphnids did not demonstrate strong seasonality. These findings suggest that the time of sampling would be important in comparing the importance of daphnids, especially the larger species. If widespread sampling were undertaken during July and August, the apparent absence of large *Daphnia* might be misinterpreted as insecticide or acidification stress. Further work should include the actual measurement of zooplankton; this study had to infer the sizes of cladocera from taxonomic names.

## **Sedimentary Diatoms as Indicators of Lakewater Quality in the Northeastern United States**

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Sedimentary diatom assemblages are being studied as one of the indicators for the Surface Waters component of the Environmental Monitoring and Assessment Program in the northeast. The top (present-day) and bottom (pre-industrial) sediment core samples collected from a large number of lakes have been analyzed for diatom assemblages. The distribution of diatom species in the region is closely related to multiple environmental variables (e.g., total phosphorus, pH, chloride, and Secchi depth). Using the weighted-averaging calibration and regression approach predictive models have been developed to infer many of these variables. In addition to assess the present status of the lakewater quality in the northeast, diatom assemblages have provided historical assessment of change in lakewater conditions since pre-1850. Distinct lakewater quality changes have been identified in the northeast as a result of anthropogenic activity in the region.

## Maryland Biological Stream Survey: Development of a Fish Index of Biotic Integrity

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As a step towards determining the extent of degradation in non-tidal streams, a multi-metric Index of Biotic Integrity (IBI) based on fish assemblages was developed for the Maryland Biological Stream Survey (MBSS). The MBSS is a probability-based statewide sampling program designed to assess the status of biological resources and to evaluate the effects of anthropogenic activities. We used data from 419 MBSS sites sampled in 1994-95 to develop the IBI. Two distinct geographic strata, corresponding with ecoregional and physiographic boundaries, were identified via cluster analysis and multivariate analysis of variance (MANOVA) as distinctly different groupings of species. Reference conditions were established based on minimally degraded sites. We quantitatively evaluated the ability of various attributes of the fish assemblage (candidate metrics) to discriminate between these reference sites and sites known to be degraded, using statistical tests and classification efficiency. Final formulations of the IBI were selected for each region based on high classification efficiency and broad representation of fish assemblage attributes. Fish IBI scores for 1995 MBSS sites spanned the full range of biological conditions, from optimal to severely degraded. Over all six basins sampled in 1995, half of the stream miles fell into the range of optimal to non-degraded. Roughly 25% showed some level of degradation. The IBI will be used in conjunction with physical and chemical data to answer critical questions about the health of Maryland streams and the relative impacts of human-induced stresses on the state's aquatic systems.

## Comprehensive Sediment Quality of the NY/NJ Harbor Estuary

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The New York/New Jersey Harbor Estuary is in the center of the most populated and industrialized area in the U.S. Years of accumulated and recent toxics contamination, primarily in sediments, has resulted in fishing bans, consumption advisories and controversy regarding disposal of dredge spoils. A reliable baseline assessment of sediment quality was essential to the development of a management strategy to address these issues. A two-year program was designed to characterize the surficial sediment quality of the Harbor. This program was based on the EMAP probability-based approach for describing ecological condition. Synoptic measurements of benthic macroinvertebrate assemblages, toxicity and chemistry were made at 168 stations in 6 sub-basins of the Harbor. Areal estimates of condition were made for each sub-basin and for the Harbor as a whole. Chemical contamination was found to be widespread, with all of the Harbor stations having at least one chemical exceeding an ER-L concentration and 50% of the Harbor exceeding at least one ER-M concentration. A toxicological response was observed for 45% of the Harbor. Impacted benthic macroinvertebrate communities were identified in more than half the Harbor and were strongly associated with chemical contamination.



## Monitoring of the Water and Sediment Quality of Lake Ontario

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Lakewide chemical and biological data of both the water column and the surface sediment for Lake Ontario have been limited. In response to the need for comprehensive and representative chemical and biological data for Lake Ontario, a large-scale monitoring project for Lake Ontario was implemented in September of 1994. The ambient data was collected to determine the distribution, magnitude, and impact of chemicals of concern (COCs) throughout the lake. In addition, the data will support the investigations of the Four Parties under the Lakewide Management Plan (LaMP) for Lake Ontario. Water column and sediment samples were chosen using a Randomized Tessellation Stratified design, in which a point is selected at random in each cell of a randomly located grid. The EMAP base grid was used for the water column samples, resulting in 29 sample sites in the lake. The sediment samples were selected using a three-fold intensification of the EMAP base grid in the depositional zone of the lake and the base density elsewhere, for a total of 58 sediment sample sites. Sampling of the water column was determined by randomly selecting a depth between the surface and the bottom. The results for selected metals and organic compounds will be shown using cumulative distribution function graphs (CDF). The CDF graphs will indicate the percent area of Lake Ontario that have sediments chemical levels that fall below certain established criteria levels. The sediment criteria levels used for this project are based on the long term effects which the contaminants may have on the sediment-dwelling organisms as determined by D. Persaud and R. Jaagumagi for Ontario's Ministry of Environment, from the No-Effect Levels to the Severe-Effects Level.



## EMAP in the Carolinian Province: Environmental Quality of S.E. Estuaries

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EMAP in the Carolinian Province was conducted to assess conditions of S.E. estuaries from Cape Henry, VA through the Indian River Lagoon, FL. About 100 stations were sampled each summer during 1994-95. At each station, synoptic measurements were made of sediment contamination, toxicity, and in-situ biological conditions. Random sampling was used to support probabilistic estimates of percent degraded vs. integrated estuaries. In both years, most of the province (64% in 1994 and 53% in 1995) showed little to no evidence of degraded benthic assemblages, contaminated sediments in excess of bioeffect guidelines, or significant sediment toxicity (based on *Ampelisca abdita* and *Microtox* assays). The co-occurrence of a degraded benthos and adverse exposure conditions (either high sediment contamination or significant toxicity based on the above assays) was found at 16 of 82 random sites in 1994 (representing 18% of the province) and 18 of 86 random stations in 1995 (representing 25% of the province). Most of these stations were in North Carolina. Additional localized impacts not accounted for in the above estimates of degraded estuaries were detected at nonrandom supplemental sites near potential contaminant sources.

## Everglades Ecosystem Assessment: Monitoring for Adaptive Management

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A monitoring study of canal and marsh populations was initiated in September 1993 to determine the extent and magnitude of total (HgT) mercury and methylmercury (MeHg) in water, sediment/soil and fish with associated water quality parameters. Probability samples permitted consistent estimates of mercury contamination in the canal and marsh systems draining this 4000 square mile geographic area. Principal component and factor analyses of both canal and marsh data partitioned HgT in fish and MeHg in water as one component with total phosphorus (TP), total organic carbon (TOC), and sulfate (SO<sub>4</sub>) aggregated as a second component. Significant north to south spatial gradients existed in constituents with geometric means ranging from 78-12 ug TP/L, 26-11 mg TOC/L, 27-3 mg SO<sub>4</sub>/L, 0.6-0.07 ng MeHg/L, 42-164 ug HgT/kg in fish and a bioaccumulation factor (BAF) from 2-8 x 10<sup>5</sup>, respectively (north - south) indicating similar gradients in both canal and marsh systems. HgT in the prey fish *Gambusia holbrooki* was significantly higher between Alligator Alley and Tamiami Trail; however, high fish mercury concentrations extend south into Everglades National Park. MeHg in marsh system water was 2 to 3 times higher than MeHg in canal water (i.e., 0.6 - 0.2 ng/L) indicating the marsh contributes MeHg to the canals. In addition, the marsh system fish had significantly higher total mercury concentrations than did canal system fish. Both the production of MeHg and food chain dynamics are thought to be important in the bioaccumulation throughout the system. A comparative ecological risk assessment will evaluate threats to ecological resources due to mercury contamination, phosphorus enrichment, surface water management and wetland habitat alteration.

## **Assessment of the Condition of Agricultural Lands in Six Mid-Atlantic States**

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The EMAP Agricultural Lands Resource Group measured indicators of the condition and sustainability of agricultural lands in six mid-Atlantic states in 1994 and 1995. Indicators were selected to reflect crop productivity and land stewardship on annually harvested herbaceous crop (AHHC) land, which covers almost 10% of the land area in this region. Overall, condition of agricultural lands in the mid-Atlantic region is good. Among the favorable results: crops in general outperformed crops grown in the 1980s, with a mean observed/expected yield index greater than one; almost 2/3 of the AHHC land is covered by crop rotation plans, with the remaining land mostly in hay fields; insecticides were applied to less than 20% of AHHC land, and less than 20% of the land where pesticides were applied has high to moderately high potential for pesticides leaching into groundwater. Among the less favorable results: the mean soil quality index fell in the low end of the moderate range, largely because of low carbon content; and integrated pest management (IPM) is practiced on less than 20% of AHHC land. Other indicators revealed crop differences: hay showed more efficient use of nitrogen than seed crops; and untilled sites, which are mostly hay, had more microbial activity (indicating more nutrient cycling) than tilled sites.

## **Canada's Ecological Monitoring and Assessment Network: Where We are at and Where We are Going**

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Canada has established a National Ecological Monitoring and Assessment Network (EMAN). The Network's operating objective is to understand what changes are occurring in the ecosystems and why. Each site is designed to have long-term multi-disciplinary monitoring programs in place with supporting research and manipulation experiments. About 80 sites have been incorporated into the Network. A Directory is available and a list of the Goals, Objectives, and Deliverables for many of the sites is also available. Information can be obtained on the Website at <http://www.cciw.ca/eman/>. The Network is operated in conjunction with a program of developing national environmental indicators with increasing emphasis on indicators of sustainable development. A series of environmental assessments are being produced that are issue and/or area focused. The assessments are designed as support for policy decisions. The overall program of data gathering, using standard indicators, leading to environmental assessment reports, has a

national coordinating office.

### **Ecological Indicators for Assessing Reference Wetlands at a Watershed Scale**

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Human activities produce stressors, such as sedimentation, hydrological modification, and habitat fragmentation, causing wetland functions to change. These stressors can be assessed using specific ecological indicators. We have used a suite of biotic and abiotic ecological indicators to assess the condition of a set of reference wetlands in Pennsylvania. The reference wetlands were classified into eight subclasses, using a regional hydrogeomorphic (HGM) key. The classes (and subclasses) are: depression (isolated, riparian), riverine (headwater floodplain, mainstem floodplain), slope, impoundment (beaver, human), and fringe. These HGM subclasses differ in their respective soil characteristics, plant communities, hydrologic and water quality signatures, sedimentation rates, and wildlife habitat potential. They also span a disturbance gradient. Results show that birds respond to changes in landscape patterns that occur on a regional scale. Amphibians respond to habitat disturbance, but more locally. They also are impacted by acidification due to atmospheric deposition and coal mine drainage. Wetland plant communities respond predictably to hydrological modifications and changes in sedimentation rates. Not all indicators are related directly to HGM classification. Wetland wildlife communities respond more directly to vegetation structure. The computation of landscape metrics also extends beyond wetland HGM classes. Thus, HGM classification, with landscape disturbance and vegetation modifiers, provides a useful framework to organize wetland functional assessments at a watershed scale.

## Measurement and Prediction of Sedimentation Rates in Central Pennsylvania Wetlands and their Impacts on Wetland Plant Communities

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Sedimentation rates and deposited sediment characteristics in twenty-five wetlands in central Pennsylvania were measured during the period Fall 1994 to Fall 1995. Wetlands were primarily located in four watersheds, and represented a variety of Hydrogeomorphic (HGM) classes and surrounding land use. Sedimentation rates were measured via the placement of one hundred thirty five Plexiglas disks. Annual organic and inorganic loadings and predominant particle size were determined. Sedimentation rates ranged from 0 to 8 cm/year, with sedimentation rates significantly correlated with surrounding land use and HGM type. All wetlands in an agricultural context experienced high sedimentation rates. Deposited material in undisturbed wetlands was correlated with HGM type; depressional wetlands received significant amounts of organic material, while slope wetlands received moderate amounts of primarily mineral material. Sedimentation rates in riverine wetlands was negatively correlated with stream energy, with wetlands located on high-energy mainstem portions of the stream exhibiting minimal accretions of material, either mineral or organic. Characterization of wetland plant communities in these same wetlands showed clear associations between various plant functional groups and ability to tolerate sediment. Annuals such as jewelweed (*Impatiens capensis*) and lady's-thumb (*Polygonum persicaria*), and perennials such as rice cutgrass (*Leersia oryzoides*) and cattail (*Typha latifolia*) showed associations with high sedimentation rate environments, while species such as tussock sedge (*Carex stricta*) and St. Johnswort (*Hypericum* sp.) were associated with low sedimentation rate environments. These observations were supported by greenhouse germination trials of nine species of wetland plants under a variety of sediment depths, ranging from 0 to 2 cm.

## **Songbird Community Index Conveys a Landscape Perspective of Ecological Condition**

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We propose an index of ecological condition based on associations between songbird guild composition and local and large-scale habitat features. Interpretation of the index goes beyond bird population information to address structural and functional elements of ecosystem integrity. We selected songbirds because of their presence across multiple resource types. As a result, the index complements biological monitoring in discrete resources and at smaller scales to provide an integrated landscape perspective for ecological risk assessment. The index was developed and tested in the central Appalachians as part of EPA's Mid-Atlantic Highlands Assessment (MAHA). We first grouped regional songbird species into guilds based on physiological and behavioral characteristics. In 1994, we conducted a pilot study to determine if guild composition reflects the status of ecosystem properties such as niche diversity and landscape disturbance. We selected 34 sites of known ecological condition along a stress gradient from best attainable to severely degraded. At each site, we collected bird and vegetation data along a 2-km transect, and quantified land cover pattern using aerial photography for the 314-ha circular area bisected by the transect. Results from the pilot study demonstrate that the songbird index is able to distinguish among five distinct categories of ecosystem condition. In addition, index values suggest thresholds of land-cover change where significant changes in ecosystem condition occur. In 1995-96, we applied the index at 126 probability-based sites region-wide. Analyses to date have resulted in a preliminary assessment of ecological condition for the MAHA area. We propose that the songbird index, based on guild composition rather than traditional diversity measures, is applicable to other regions with minor adjustments for geographic differences in songbird community composition.

## **Effects of Measurement Scale on Relationships Between Landscape Structure and Breeding Birds in the Bighorn Mountains of Wyoming**

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Human-caused fragmentation of forests and its consequences on breeding birds has been studied primarily using a patch-centered sampling scheme. As a result, the effects of landscape structure and extent are confounded. Landscape oriented studies usually have been conducted at only one scale. Our objectives were to evaluate the effects of landscape structure on bird diversity at four different measurement scales (6 - 3600 ha). We hypothesized that forest extent and composition are more important indicators of bird diversity at small scales whereas spatial patterning is more important at large scales. We systematically sampled at over 2700 sites at 500-m intervals across the Bighorn National Forest in Wyoming during 1994 and 1995 using the variable circular plot approach and the program DISTANCE to estimate bird composition and abundance. TM satellite imagery was used to characterize forest composition, extent and structure using ARC/INFO and FRAGSTATS. We quantified the independent effects of forest composition and structure on bird diversity at different scales using ANOVA and regression analysis and modified our statistical models to account for autocorrelation. Our results are discussed in terms of the implications for EPA's Environmental Monitoring and Assessment Program.

## **Spatial Complexes from Compound Clustering as a Prospective Basis for Landscape Indicators**

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Landscape indicators must embody spatial organization that reflects differential ecological sensitivity to multiple stressors. Landscape dynamics as influenced by stressors are likely to be multi-factor, and cannot necessarily be readily anticipated. Response to stresses may be expressed either in spatial organization or condition of pattern elements or both. Use of definitional classes as pattern elements may mask organizational features at a given scale, and becomes even more problematic for multi-scale aspects of landscape pattern. A degree of informational landscape self-organization is needed to obtain multi-scale indicators that resonate with state of nature as conditioned by human influence. Multi-phase clustering followed by determination of echelons on spatial partitions arising from superposition of cluster-based tessellations can provide an objective approach to addressing this aspect of environmental monitoring. Clustering regimes must be standardized to achieve objectivity, but clustering variations can be used to assess sensitivity. It also becomes important to recognize different categories of environmental information relative to temporal stability and noise level in configuring the clustering scenarios. Definitional classes such as land-use and watersheds can be incorporated as strata, if appropriate. In effect, such composite clustering regimes become computer intelligent landscape perceptors.



## **EMAP Wetlands: Wetland Condition Indicators in the Prairie Pothole Region of the United States**

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We describe a pilot program and probability based research effort designed to evaluate indicators of wetland condition in the Prairie Pothole Region of the United States. Site specific and landscape indicators were chosen for evaluation. The best biological indicator of wetland condition in the pilot program was plant species richness in wet meadow zones of wetland basins. Other condition indicators showing promise included: sedimentation rates, sediment phosphorus, and kilometers of drainage ditch per hectare. The demonstration project was designed to evaluate a suite of the pilot indicators using a probability based sampling design. Sampling was conducted on 45, 640 km<sup>2</sup> hexagons in the Prairie Pothole Region of North Dakota. Individual wetlands chosen from a probabilistic based sample of the region were used to evaluate basin specific indicators including biomarkers, soil characteristics, and vegetation. Because many animal species use wetland basins and surrounding uplands, the hexagon was the sampling unit used to evaluate landscape scale indicators such as breeding pair densities of waterfowl, amphibians, and flying stages of invertebrates. Wetland condition in the PPR is closely associated with upland cover and land use so a GIS with land cover was developed for each hexagon. Preliminary analyses comparing upland characteristics to wetland condition will also be presented.

## **Multi-scale Monitoring for Detection of Regional Biogeochemical Change: A Central Appalachian Case Study**

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The observation of dramatic change in the acid-base chemistry of stream waters following the gypsy moth infestation in western Virginia illustrates the utility of long-term ecosystem monitoring conducted on appropriate spatial and temporal scales. Coordinated monitoring of forested mountain watersheds on public lands in the region is conducted through the Shenandoah Watershed Study and the Virginia Trout Stream Sensitivity Study. A system of streams representing different watershed lithologies are sampled for analysis on seasonal, weekly, or hourly time scales. Extensive coverage is provided by quarterly sampling of 68 regionally distributed streams. More-intensive coverage is provided by weekly sampling and continuous discharge gauging of five streams, three of which are instrumented for automatic collection of storm-flow samples at 2-4 hour intervals. The southward-advancing range of the gypsy moth resulted in 2-3 years of heavy forest defoliation in many of the study watersheds in the late 1980s and early 1990s. Change in the baseflow composition of stream waters following this defoliation included increased concentrations of nitrate, decreased concentrations of sulfate, and increased concentrations of base cations. Change in stormflow composition included reduced acid-neutralization capacity and increased acidity. After several years of response following the defoliation episode, the composition of affected streams is now approaching predefoliation concentration levels.

## **Time and Space Scales and Ecological Responses: Implications for Indicator Analyses and Presentation**

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From its inception, a major EMAP focus has been the development and testing of ecological indicators to assess the status and trends in the condition of ecological resources on a regional and national basis. An underlying assumption in some of this research was that new indicators might be required because of the larger spatial areas and longer time periods that are being assessed. Until quite recently, most ecological studies have been conducted on time scales of 1 yr. and space scales of a few m<sup>2</sup>. Therefore, EMAP indicators that integrate over larger time and space scales or that provide cumulative responses to environmental forcing functions are desired over ecological indicators that have traditionally been monitored. Greater emphasis was placed on slower response indicators such as fish, birds, or soil/sediment measures and less emphasis on faster response indicators such as water quality, phytoplankton, or air measurements. However, if appropriate aggregation or averaging procedures are used, based on the underlying time and space scales inherent in the questions being asked, ecological responses for larger spatial areas over longer temporal periods can be determined from these rapid response indicators. This paper will discuss general guidelines for determining appropriate aggregation or averaging procedures for rapid response indicators based on the time and space scales of the questions being asked. Status, trends, and association analyses among cumulative and rapid response indicators will be used to illustrate these general guidelines.

***EMAP Symposium Posters***

## **A Bioassessment of Lakes Using the EMAP Macroinvertebrate Indicator**

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The Environmental Monitoring and Assessment Program (EMAP) conducted a Lakes Pilot Project during the summer of 1991 on 19 New England lakes. The macroinvertebrates were one of several biological indicators evaluated and used in detecting stressors in these lakes. Fifteen lakes were selected based on temperatures (warm, cold), sizes (large, small), and potentially anthropogenic disturbances (residential, agricultural, silvicultural, and fish stocking). Four reference lakes were also selected to represent least stressed lakes of each type. Three replicate macroinvertebrate samples were collected at each site with a stainless steel petite Ponar grab sampler, using EPA methods. The Macroinvertebrate Indicator, using twelve metrics (including taxa richness measures, composition measures, and pollution tolerance measures), and Lake Biological Integrity Index (LBII) scores were successful in detecting the levels of known stressors for 17 of the 19 lakes. All LBII scores for the stressed lakes were higher than the control lakes, and MANOVA ( $P = 0.0001$ ) demonstrated that the LBII scores of the control lakes were significantly different from the stressed lakes.

## **Adirondack Long-Term Monitoring Project**

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The Adirondack Lakes Survey Corporation (ALSC) initiated a long-term monitoring program (LTM) in 1992 to evaluate changes in water chemistry in 52 Adirondack waters. This project was developed in cooperation with researchers from Syracuse University and is funded by the Empire State Electric Energy Corporation (ESEERCO), the NYS Department of Environmental Conservation, and the U.S. Environmental Protection Agency. The Adirondack LTM involves monthly collections of water samples from 52 lakes that are representative of five major lake classes in the region and weekly from three low-order streams. Each month one-liter water samples are collected and returned to the ALSC laboratory for analysis of 24 chemical parameters. Sixteen of the 52 monitoring lakes are part of a previous long-term monitoring program conducted by Syracuse University that now provides a continuous 14-year data record for these lakes. In addition to monthly sampling for all waters, a subset of lakes are selected for weekly sampling during the spring snowmelt period. Episodic acidification continues to be significant in both lakes and streams during the snowmelt period with more than 65% of the lakes showing pH below 5.2 in 1994. Overall, time series analysis of 16 of the 52 lakes shows a general decrease in concentrations of  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ , and base cations corresponding to decreases in deposition, while pH appears to be increasing in most lakes. Data also shows pronounced chemical differences among different lake categories.

## **The Wood-Pawcatuck Watershed Partnership Initiative, a Case Study for New England**

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The Wood-Pawcatuck Watershed was recently selected as the model case study for New England for Federal, State, and Local partnerships to implement the new, national, watershed-based environmental management strategy. A Watershed Partnership Initiative is being built to facilitate this new way of doing business. The goals of this Initiative are to promote comprehensive, proactive environmental management within the Watershed and to encourage informed decision making at all levels, starting with citizens and local communities. The availability of good quality environmental data and information is essential to smart, proactive decision making. This presentation reviews the data, information, and environmental indicators currently used to assess water quality and attainment of use designation within the Watershed. Improvements in selection and use of environmental indicators are suggested to assess water quality and to facilitate integration of environmental assessments across resource types: lakes, streams, rivers, and estuaries. These assessments need to be responsive to public concerns about sustainable resources and the consequences of development. A preliminary identification of future vulnerabilities will be made.

## Estimating Lake Trophic Condition in the Northeastern United States

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During the summers of 1991-1994, a scientifically designed sample survey with a sample size of 344 lakes was conducted on lakes throughout the northeastern United States. Trophic state results (expanded to the 11,076 lake population) from this statistical sampling were compared to a large existing, but non-statistical, data set (2,758 lakes) for the same area and contrasted with lake trophic state information published in the 1994 National Water Quality Inventory Report to Congress (305(b) Report). Lakes across the entire northeast were determined from EMAP data to be 37.9% ( $\pm$  8.4%) oligotrophic, 40.1% ( $\pm$  9.7%) mesotrophic, 12.6% ( $\pm$  7.9%) eutrophic, and 9.3% ( $\pm$  6.3%) hypereutrophic. These EMAP results are quite similar to those of the large non-statistical data set across the entire region. However, the 305(b) report identified a much higher proportion (32.2%) of lakes in eutrophic condition and a much smaller proportion (19.8%) in oligotrophic condition than did the EMAP survey data. Probability survey sampling designs have several advantages over other approaches if regional condition assessment is the goal. The most significant advantage is the ability to obtain objective condition estimates with quantifiable uncertainty.



**Wetlands And Watershed Influences on Lake Chemistry: A GIS Characterization  
of the Oswegatchie-Black River Watershed in the Adirondack Park of New York  
State**

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The 2.4 million ha Adirondack Park is experiencing the effects of acid deposition and watershed development on its lake and wetland resources. This EPA sponsored project developed and interpreted diverse mapped information for a 400,000 ha watershed using ArcInfo. Phase I created the database for 1,223 ponded watersheds and over 60,000 wetland ha with more than 200 NWI wetland types. Phase II provided eight additional digital coverages: upland land cover (using LANDSAT Thematic Mapper imagery); soils; surficial and bedrock geology; APA land use map (including public lands); existing residential development; forest age; fire history; and atmospheric deposition. This digital database currently is being linked with key lake chemistry tabular data from the ALSC Long Term Monitoring waters. Sample GIS analyses are shown including the correlation of lake chemistry with wetlands, upland land cover, and predominant geology. The use of organic soils and wetland cover types as predictors of peatlands is also discussed.

## **Determining the Representativeness of Historical Long-Term Monitoring (LTM) Lake Watersheds**

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This study was an investigation of how well the historical LTM lake watersheds have represented the different types of watersheds found in the region. The results reported were based on a sample of 97 randomly selected lake watersheds in the Adirondack Park-portion of the Oswegatchie-Black Watershed, NY. The attributes selected to describe the watersheds were those features known to influence surface water chemistry including land cover, soils, hydrology, and geology. Geographic information systems (GISs) were used to describe the watersheds with 48 physical attributes at a small map scale (1:250,000). The lake watersheds were statistically grouped (clustering analysis) based on physical similarity to investigate the different types of lake watersheds and their distributions within the region. Seven physically different types of lake watersheds were found. Lake watersheds with similar physical attributes had similar surface water concentrations of acid neutralizing capacity (ANC)-related nutrients. Attributes that were highly correlated with one or several ANC-related nutrients for one group of lake watersheds were very poorly correlated with the same nutrients in other groups of lake watersheds. These results suggested that the lake watersheds in this region were not a single homogeneous population from the perspective of nutrient cycling. To adequately monitor the region and diagnose systems at risk, all types of lake watersheds need to be represented in the sampling design. After the seven types of lake watersheds were defined (in multivariate space), discriminant analysis was used to determine how well the LTM sites represented the lake watershed heterogeneity in the region.

## Macroinvertebrate Indices of Environmental Condition for Lake Ontario

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Lakewide biological and chemical data were collected from surficial sediments of Lake Ontario to examine benthic macroinvertebrate community structure as an indicator of environmental condition. Sediments were collected from 55 locations in Lake Ontario using a three-fold EMAP grid during August and September, 1994. The samples are representative of the entire lake sediment, with more sampling effort in the depositional zones of the lake. Benthic invertebrate community measurements (total abundance, *Diporeia* abundance, species richness and diversity) were used to assess the biotic integrity of the lake and to seek associations between ecological measurement endpoints and measures of environmental quality (grain size, TOC) and of sediment chemical stress (toxicity, PAHs, PCBs, pesticides, and metals). Patterns of lower abundance of *Diporeia* and higher species richness were found in nearshore samples at depths less than 40 meters. Abundance of *Diporeia* reached a maximum at 60-80 meters, whereas species richness remained constant at depths greater than 50 meters. There were distinct patterns of association between community endpoints and measures of both environmental quality and stress.

## **Environmental Indicators Development in U.S. EPA Region 3**

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USEPA Region 3 is undergoing a Strategic Planning process. Through this (data driven) planning process we are developing environmental indicators which are designed to address three of the Region's Strategic Environmental Goals: Acid Deposition, Ground-level Ozone, and Nitrogen loading to the Chesapeake Bay. Development of the environmental indicators is based on the 'family of measures' categories of stressor-level, source condition and resource health indicators. Our environmental indicator development began with source level indicators and is proceeding to the stressor level indicators. At the stressor level we are characterizing the ambient condition throughout Region 3 relative to the priority environmental goals. From stressor-level indicators, we will work to describe and identify the links to resource health. Resources of concern will include biological, ecological and human health endpoints in the Mid-Atlantic. The stressor- and source-level indicators will be presented by poster.

### **Public Use Database from EMAP's Agricultural Lands Resource Group**

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The Agricultural Lands Resource Group (ALRG) is in the process of creating a public-use database from surveys conducted in the Mid-Atlantic region during 1994 and 1995. This database will be available via the Internet and will allow a user to reproduce and extend the research conducted by the ALRG (this is important because our group will no longer exist after April). The database will include data on soil physical and chemical properties, soil microbial biomass, ant abundance and identification, and farm operator responses to questions about land use, management practices and yield. In our poster we will briefly describe these variables, outline the structure of the database, and provide several examples on how to calculate statistically valid estimates based on our sample design.

## **A Framework for Assessing the Condition of Agricultural Lands**

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The foremost goal for agricultural lands is production of food and fiber for human use. Other desired outcomes can be considered as goals for the larger agricultural landscape, and they sometimes function as constraints on production; among them are clean air and water, wildlife habitat, and aesthetically pleasing landscapes. The condition of agricultural land is defined by its productivity and the degree to which valued biotic and abiotic resources are conserved and protected. Agricultural land in good condition is productive and does not compromise valued resources; sustainability is the ability to maintain good condition over time. From these premises, our indicators were selected to reflect crop productivity and land stewardship. Indicators measured for the Mid-Atlantic Study included crop yield, soil quality, and crop rotation indexes, frequency of use of integrated pest management practices, nitrogen use efficiency, pesticide leaching risk, and ant diversity. In making an assessment, condition is reported for each indicator. An overall condition may also be reported, but would depend critically on the relative weighting of the goals for agricultural lands. For sustainability, one can examine trends in crop productivity and stewardship practices.

## Spatial and Temporal Patterns in Microbial Respiration of Stream Sediments

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Microbial respiration on fine-grained stream sediments was measured in microcosms incubated at 92 1st -3rd order sites in the Central Appalachians in 1993 and 1994. The sites were randomly selected from a fixed grid of potential sites, as a part of EPA's Environmental Monitoring and Assessment Program (EMAP). This probability-based sampling facilitates statistical comparisons among spatial (stream order, basin, drainage system, physiographic province, and region) and temporal (intra- and inter-annual) scales, and among disturbances classes (acidification, mine drainage, watershed disturbance). Respiration ranged from 0 to 0.522 g O<sub>2</sub> g<sup>-1</sup> AFDM h<sup>-1</sup>, and was positively correlated with streambed sediments and woody debris, stream temperature, water chemistry and riparian disturbances, and negatively with canopy density. Respiration was significantly higher in valley streams compared to either ridge or plateau streams. There were no significant differences in respiration among drainages, basins, or stream orders, nor were there differences in respiration within or between years. Thermal sensitivity (Q<sub>10</sub>) for the region was 1.76±1.28 and ranged from 0.89±1.46 for 1st order streams to 3.22±2.04 for streams in the Potomac River basin. There were no significant differences among any of the spatial scales examined or between years. Stepwise multiple regression of respiration, using the same set of physical and chemical parameters as the independent variables, revealed that the amount of variance in respiration explained by environmental factors was inversely proportional to spatial scale.

## A Spatially-Oriented Conceptual Model for the Mid-Atlantic Integrated Assessment

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Attainment of goals in regional assessments of ecological condition, such as the Mid-Atlantic Integrated Assessment (MAIA), requires a conceptual understanding of the principal environmental components of the region and the processes linking these resources. In support of MAIA, a general systems perspective is being applied to develop a conceptual model which addresses multiple spatial scales nested in hierarchical fashion. At the largest spatial scale is the entire MAIA region, defined by natural and political (state) boundaries. Nested within this region with increasing spatial resolution are watersheds and coastal bays, basins within watersheds, reaches within basins, and so on. The final degree of resolution of the conceptual model is dictated by regional assessment questions, and the detail required to understand the processes affecting resource condition. Ultimately, the "black box" nature of the conceptual model will be replaced with explicit quantitative descriptions of the condition of resources and the processes linking them. This conceptual model will serve at least three important functions in MAIA: 1) it will focus research activities by identifying key environmental processes linking ecological components at different spatial scales; 2) it will aid in identifying and revising fundamental management questions regarding environmental condition; and 3) it will prescribe the scales at which environmental processes should be evaluated to answer individual assessment questions.

## **Assessing Streams' Vulnerability to Mine Drainage in the Mid-Atlantic by Mapping Probability Sample Data from EMAP and the National Stream Survey**

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A new approach was evaluated for use in assessing impacts from stressors on aquatic systems. Two probability surveys of stream chemistry in the Mid-Atlantic Region, the National Stream Survey Study (NSS), and the Environmental Monitoring and Assessment Program/Mid-Atlantic Highland Assessment (EMAP/MAHA) study were used to map estimates of the percentage of stream miles impacted by mine waste. Within the study area, the NSS sampled 433 stream segments in spring 1986. In the EMAP study, 508 sites were sampled during late spring 1993-1995. Macroinvertebrate samples were also collected at these same EMAP sites. A chemical classification scheme was used to identify sites (both acidic and nonacidic) impacted by mine drainage. Using the EMAP probability design, we then estimated the percentage of stream length in various ecoregions impacted by mine wastes. The results of these analyses were used to construct colored maps of the Mid-Atlantic Region using aggregations of Level IV Omernik ecoregions. Over 50% of the stream length in the mixed land use, Greenbrier Karst, and Cumberland Mountains Subcoregions of the Central Appalachians were affected by mine drainage. In the Western Allegheny Plateau, 26% of the stream length were mining impacted. The macroinvertebrate data were put into a candidate index called the Stream Benthos Integrity Index (SBII). Excellent, good, fair, poor, and very poor SBII scores were also plotted on the aggregated Ecoregion map. Areas of severe, moderate, slight, and undetectable (> 50%, 25-50%, 10-25%, and 1-10% of stream length, respectively) mine waste exposure were compared to the SBII scores. Results indicate that this approach is useful in illustrating stressor extent, biological condition, and a method for evaluating chemical and biological assessment models.



## **Influence of Stream Stability on Brook Trout Abundance and Species Diversity in Maryland Appalachian Streams**

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Stream stability is an important variable affecting the quality of aquatic habitats. Stream stability can be defined as the ability of a stream to carry the water and sediment of the watershed, enabling the stream to maintain its dimension, pattern, and profile without aggrading or degrading. Disequilibrium in the sediment supply to a stream causes negative alterations in stream function and morphology, and negatively affects the fish populations. We examined the effect of stream stability on brook trout (*Salvelinus fontinalis*) populations and species diversity in 44 stream segments in western Maryland. Stream stability was measured using the riffle stability index or RSI. Brook trout abundance and species diversity showed no significant relationships to RSI. Brook trout abundance and species diversity measures varied throughout the range of RSI values indicating that brook trout and other fishes reside in Central Appalachian streams that are aggraded, degraded, and stable with no preference to any specific stream type. We believe that the effects of a widespread, catastrophic flood which occurred in January of 1996 throughout the study area may have overwhelmed the effect of RSI on fish populations in the study segments.

## Extent of Fish Tissue Contaminants in Mid-Atlantic Highland Streams

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Fish were collected for tissue analysis from wadeable streams in the Mid-Atlantic Highlands for EPA's Environmental Monitoring and Assessment Program (EMAP). Fish collections and tissue analyses were designed to assess regional risks of consumption of fish by either wildlife or humans and track how risks change with time in a region. The fish tissue indicator was also meant to be used in conjunction with other EMAP indicators to indicate probable causes of stream degradation. To accomplish this, two categories of fish samples were collected from as many sites as possible. The primary target species were selected because the adults are small (<100mm) and short-lived (e.g., dace, chub, sculpins, stonerollers, shiners, and darters), and potentially ubiquitous. The secondary target species are long-lived (>3 yrs) and large (>150mm) as adults (e.g., sunfish, bass, suckers), and likely to concentrate compounds under prolonged exposures. Whole fish were composited from each target group to obtain a minimum sample (50 g for primary species; 3-5 fish > desired size) and analyzed for metals and organochlorine compounds (pesticides and PCBs). Mercury was not detected as often or at the levels found in EMAP lake surveys.

## **An Interactive, Spatial Inventory of Environmental Data in the Mid-Atlantic Region**

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To improve understanding of ecological condition in the mid-Atlantic, the U.S. Environmental Protection Agency (EPA) is working with federal, state, local, and private partners to produce an interactive, spatial inventory of environmental data in the region. Data identified by the inventory will contribute to a regional ecological assessment currently in preparation by EPA's Office of Research and Development and Region 3. An interactive demonstration of the developing inventory is proposed for the Symposium. Accessible on the Internet, the inventory will display maps of sampling locations, lists of measurements, and design information for some of the ~85 programs currently included. Examples of user-defined queries will also be presented, resulting in customized maps that satisfy selected constraints. (For example, "Display sites from all programs with a probability design that measure dry deposition and nutrient availability in soils.") By September, open-ended queries of the inventory's 500-field database will be available online. The inventory will also be used by federal agencies to design more integrated environmental monitoring and research activities. Its methods and format are currently being evaluated by the White House Committee on the Environment and Natural Resources as a potential prototype for completing additional regions of the U.S.

## Ecological Indicators of Forest Integrity and Sustainability

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We are developing indicators of forest ecosystem integrity and sustainability. A conceptual model, using the ecological risk assessment framework, was developed to assess the response of Pacific Northwest forests to environmental and anthropogenic stressors. Our approach focuses on the functioning of forest ecosystems, specifically on the carbon and nitrogen cycles. We have collected data at intensive sites along an elevation gradient in the western Cascades of Oregon that are used to parameterize the General Ecosystem Model (GEM). This model is used to identify the key ecosystem processes that could change when the ecosystem is stressed (e.g., global change and ozone). We will then identify and develop indicators for rhizosphere processes (e.g., DNA fingerprints), ecophysiological processes (e.g., carbon allocation to fine roots), ecosystem functioning (e.g., nutrient leakage), and landscape processes (e.g., regional productivity). We will use other sites in the western Cascade region (e.g., Forest Service and LTER) to validate and verify the performance of the indicators.

## Submerged Macrophytes as Ecological Indicators in the West Indian Province

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As part of the 1995 EMAP base sampling in the West Indian Province (WIP), we independently sampled locations which were identified in the base sampling as having submerged aquatic vegetation (SAV) and measured a suite of parameters to test their utility as indicators of estuarine trophic state. The primary indicators included species-specific SAV cover (characterized by the Braun-Blanquet scale), species-specific seagrass short-shoot density and biomass, shoot-specific structural characteristics (e.g., leaf length, leaf width, leaf area index), epiphytic biomass, and macroalgal biomass. SAV were present at 44 of the stations we sampled in the WIP (78 total stations). This poster presentation will summarize spatial patterns in SAV distribution and abundance, and morphometrics of the seagrass *Thalassia testudinum* (Turtle grass). *Thalassia* was the most widely distributed SAV in the WIP, occurring at 39 sites. *Syringodium filiforme* occurred at 13 sites, followed by *Halodule wrightii*, *Halophila decipiens*, and *Ruppia maritima* at 10, 1, and 1 sites, respectively. Calcareous green algae were also widespread, occurring at 35 stations; *Caulerpa* spp. and *Batophora* sp. both occurred at 10 stations. *Thalassia* and the calcareous green algae were most abundant in Biscayne Bay, the Florida Keys, and Florida Bay; *Syringodium* was most abundant at the most seaward stations along the Keys. *Thalassia* short-shoot densities exceeded 900 m<sup>2</sup> at four stations, three of which were in Biscayne Bay. No SAV were observed at WIP stations from Cape Sable to Charlotte Harbor, which may reflect low sample density and the presence of stations in turbid interior water bodies.

## **A Landscape Approach for Assessing Ecological Risk in a Southwestern Watershed- -San Pedro River Case Study**

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The U.S. Environmental Protection Agency recently initiated a national approach to assess ecological risk relative to exposure to environmental stressors. A key component of this framework enlists landscape ecology as a theoretical basis from which to assess cumulative exposure to stress at multiple spatial and temporal scales. This project has focused its research into developing a system of landscape composition and pattern indicators which can be used to estimate current status, trend, and changes in ecological and hydrological condition. Specifically, it is designed to determine ecosystem vulnerability relative to large-scale natural or human-induced disturbances (e.g., climatic change and livestock grazing, respectively) using a system of landscape pattern metrics derived from remote sensing, spatial statistics, and geographic information system technology. The program has proposed a strategy of utilizing triplicate Landsat Multi-spectral Scanner imagery from the early 1970s, mid-1980s, and early 1990s to generate land cover data which is later converted into landscape pattern metrics. This process has been tested in a small watershed in southeast Arizona and northern Sonora and has been particularly related to land degradation and habitat modeling for selected wildlife species in the upper San Pedro Watershed. The preliminary results of this project are presented to 1) illustrate both the indicator and change detection strategy; 2) demonstrate the value of the approach to ecosystem and watershed management; and 3) demonstrate the potential application of the approach to a national and regional program for systematic ecological vulnerability assessment. Notice: The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development (ORD), prepared this abstract for a proposed poster presentation. It does not necessarily reflect the views of EPA or ORD. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

## **Spatial Variability of Ant Communities Following Mesquite Removal in Winter Grazed-plots at the Chihuahuan Desert**

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We studied the responses of ant communities to the environmental stressors: habitat removal by shrub removal and short-term intense grazing by domestic livestock. Spatial variability in ant communities were studied in three plots where mesquite shrubs (*Prosopis glandulosa*) were removed. Plots were grazed during winter 1994-1996. Ants were sampled by pitfall traps arranged in a 7 trap x 7 trap array with 9.14 m spacing between traps on each of the 0.5 ha plots. Results based on the relative abundances of species indicated that *Dorymyrmex* (*Conomyrma*) populations decreased over time while *Solenopsis* populations increased. Kriging maps were generated for species richness and for each group of species to examine the effects of grazing. Because ants construct nests deep in the soil, surface disturbances resulting from human and/or animal activities may be difficult to assess if measurements are made only once. We examined spatial variability over 3 years. Covariograms were used to identify the range of dependence and cross-correlation between ant communities and other variables such as shrub density and cover, soil depth, and physical locations of ant nests. Results contribute to an evaluation and characterization of ants as indicators of arid land health.

## Using Ants as a Biological Indicator in Agroecosystems

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Ants are abundant in agroecosystems and figure prominently in many ecosystem processes. They are leading predators of small insects; are involved in seed dispersal, grainivory, and pollination; move soil; and are involved in mixing plant debris in soil. Furthermore, they are easy to recognize and sample, and they have been used successfully as biological indicators. Many studies show that ant species richness and diversity track environmental gradients. There is also evidence that ants integrate information about environmental condition. In order to explore the relationship between ant communities and agroecosystem health, the Agricultural Lands Resource Group of EMAP first conducted a small survey in September 1994, at 24 sites in the North Carolina Piedmont to assess the suitability of using ants as an indicator. Then, in August 1995, National Agricultural Statistics Service personnel collected ants at over 100 field sites in Virginia and North Carolina. The selected sites were a subset of the Agricultural Lands Resource Group's sampling effort in the MAIA region, so data on soil properties and farm management were taken on these same fields. Ants were sampled along transects and trapped with pitfall traps. The ants were then identified to species. Relationships among agricultural management, soil type, and ant richness and diversity were explored with multivariate analysis. Variance studies were conducted to determine the within-transect, within-field, and the between-field components of variance. The results have implications for the use of ants as an indicator of agroecosystem monitoring.



## **The Effects of Sediment Composition on the Solid Phase Microtox(R) Assay**

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During EMAP studies in the Carolinian Province, it was observed that estuarine sediments characterized by high silt-clay content (contaminated as well as uncontaminated) consistently had low Microtox(R) EC50s. During the assay, the bioluminescent bacteria (*Vibrio fischeri*) are exposed to a sediment suspension, and the effects on light production are evaluated in the liquid phase that remains after removal of the sediments by filtration. It was hypothesized that the low EC50s of silty sediments were due primarily to adsorption of the bacteria to the silt-clay particles. Artificial sediments (mixtures of pure sand and clay) and reference sediments were used to evaluate the effects of sediment type on Microtox(R) EC50 values and bacterial counts of the liquid phase. The results supported the hypothesis, i.e., EC50s and bacteria concentrations decreased in a predictable manner as silt-clay composition increased. This sediment bias could affect the interpretation of toxicity results by overestimating the potential for contaminant effects in muddy areas. Methods of normalizing for sediment composition and developing toxicity criteria are discussed.

## **The Biomonitoring of Environmental Status and Trends Program: An Overview**

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The Biomonitoring of Environmental Status and Trends Program (BEST) is designed to assess and monitor the effects of environmental contaminants on biological resources, particularly species and lands managed by the Department of the Interior (DOI). BEST examines contaminant issues at the national, regional, and local scales and uses field monitoring methods appropriate to the issues of concern at each scale. A national network is proposed to describe the temporal trend and distribution of environmental contaminants and their effects by applying biomonitoring methods. The approach is being evaluated in fish in the Mississippi, Columbia, and Rio Grande basins. Regional assessments involve examination of impacts of contaminants on the habitats and biota in selected ecosystems. Findings are used to tailor monitoring activities to meet regional resource needs. To date, regional assessments have been conducted in the Lower Rio Grande basin, for estuaries along the Atlantic Coast, and in north-central Oregon. At the local scale, BEST uses a site-specific assessment process to evaluate contaminant effects on lands managed by DOI. The U.S. Fish and Wildlife Service has completed this assessment at over 50 National Wildlife Refuges. The National Park Service is examining its application at two National Parks. Monitoring of these three scales, along with the development of biomonitoring methods, provides information to evaluate and describe contaminant effects on biological resources.

## Managing Scientific Data: The EMAP Approach

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Many data sets used for EMAP assessments will be collected and managed by groups other than EPA as the CENR inter-agency monitoring program develops. Managing these data requires a change from a database run by EPA to a model where there is, in addition to distributed databases, truly distributed ownership and responsibility. A single integrated, consistent database, distributed or otherwise, would be a daunting political and technical task to achieve. Instead, there are common standards, data directories, and data descriptions so that data of interest can be located, downloaded, and understood. The EMAP approach is to apply increasing degrees of EMAP data management practices to a data set, based on increasing degrees of EMAP responsibility. The Data Directory keeps track of all data sets of interest. This is an Oracle database with a searchable listing of enough information about a data set for a user to determine if the data are of interest. Some of these data sets are in the possession of EMAP and are accessible on the EMAP WWW site (<http://www.epa.gov/emap/>). Some data sets are managed and documented by other organizations. The Data Catalog contains metadata about data sets in the possession of EMAP so that a user can understand enough about the methods, assumptions, and quality to use the data wisely.

## **Assessment of Aquatic and Riparian Ecosystems in a Highly Modified, Agriculturally Influenced Environment in the Central Valley, California**

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Central Valley, California, contains critical habitat for many aquatic and terrestrial biological resources. This R-EMAP project assessed the effects of a highly modified agriculturally dominated landuse on the aquatic resources of the lower portion of the Central Valley watersheds. The study area is approximately 30,000 mi<sup>2</sup> and comprises the Sacramento Valley and San Joaquin Valley watersheds below the 1000 ft elevation. Populations of interest were natural streams and man-made conveyances. Sample sites were selected to represent 13,226 miles of streams and sloughs, and 14,648 miles of conveyances within the Central California Valley and Southern and Central California Plains and Hills ecoregions. The data for 1994 and 1995 indicate that there are three distinct types of waterways within the study area: 1. natural streams, 2. man-made conveyances, and 3. natural streams managed as conveyances. Biological and physical habitat data indicate that the lower portion of natural streams from the Sierra Nevada foothills, on the east side of the valley, to the valley floor show some impairment from upstream management (e.g., dams) and land use (e.g., agriculture, construction, etc.). Streams draining the eastern part of the Coast Ranges, on the west side of the valley, were predominantly dry during the sampling index period of mid-July to September. Natural streams managed as conveyances range from highly impaired to moderately impaired. These streams are being used as main canals and irrigation canals. The streams maintain some natural sinuosity, but have been altered into a man-made conveyance. The highly impaired waterways are either dry, ephemeral, or managed to be abiotic. Conveyances range from highly to moderately impaired. Man-induced disturbances of the conveyances range from highly disturbed or managed (i.e., no riparian habitat or vegetation, no aquatic organism) to slightly disturbed or managed (i.e., some vegetation and riparian habitat, presence of aquatic organisms).

## **Presentation of Data in Linked Attribute and Geographic Space**

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The paper discusses methods for presenting data where geographic location is an important aspect of the information to be communicated. Our methods give equal consideration to presenting data in attribute space and in geographic space. We base our approach, termed map row plots, on the linked use of row-labeled plots and geographic maps. Row-labeled plots include horizontal bar plots, horizontal distribution summaries, and spectrum plots for categorical data. Although many types of geographical maps may be used, we focus on choropleth maps enhanced with relief shading based on an attribute. Successful map row plots require an efficient link between attribute space displayed as row-labeled plots and geographic space displayed as maps. We investigate alternative links between one or more row plots and one or more maps. Several examples from environmental statistics demonstrate the principles.

## **Geographic Evaluation of a National Hydrologic Database for Multi-scale Monitoring and Assessment**

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Local, regional, and national water quality reporting for federal programs relies on statistics summarizing the extent of water resources. EPA's Environmental Monitoring and Assessment Program Surface Water (EMAP-SW) project analyzed digital national hydrographic databases currently available for assessing national extent of lakes, streams, rivers, and wetlands. EPA created a national, hydrographic-consistent data base, River Reach File Version3-Alpha (RF3-Alpha), based on USGS 1:100,000 Digital Line Graphs (DLG's). We present a map of the national database and summarize geographic discrepancies discovered when we examined the database. Some problems were inherent to the DLG's while other problems were derived from RF3-Alpha processing or the original RF3-Alpha database design. Detailed examples of several discrepancies are presented in the poster. We describe additional information derived from RF3-Alpha which augmented the EMAP-SW sampling design. EMAP-SW invoked a spatially-balanced probability sample which is used for multi-scale water resource assessments. Finally, we summarize improvements to the RF3-Alpha database as it progresses to the National Hydrographic Dataset, a joint effort between EPA and the USGS.

## Using EPA's RF3 as a Frame for Sampling Streams

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EPA developed the River Reach File, Version 3 (RF3) from the digitized version of the hydrographic layer of USGS's 1:100,000 series of maps. EPA's Environmental Monitoring and Assessment Program (EMAP) has used probability surveys of aquatic resources to meet its stated objectives; RF3 has been used as a sampling frame to select the location of field sampling sites. This poster will present information about RF3 relevant to those applications, and about the aquatic character of these probability selected sites, as determined from field visits. For example, in the 1993-1995 stream pilot in EPA's Region 3, 564 sites were visited; of these 89% were on flowing streams, 4% were on streams with interrupted flow, 4% were on dry channels, and 3% had no identifiable stream channel. Analogous results will be presented from several other regional studies. Stream length is dominated by headwater streams (Strahler order = 1); simple probability sampling would locate most sampling sites there. We varied sampling intensity by (RF3) Strahler order to overcome this, and imposed a mild restriction to achieve spatial balance in the located sites. In some areas RF3 apparently lacks some stream traces existing on the base maps; we will illustrate this and how we corrected for it. Other uses and outcomes will be illustrated.

## A Study on Cleaning of Dusty Exhaust Gas by Pulse Corona

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Dusty exhaust gas is a major concern for environmental conservation because the exhaust gas contains toxic substances. The authors have carried out research to clean the exhaust gas by electrical discharge. Decomposition of the toxic gases was attempted by pulse corona. The pulse corona was produced by a power supply. The power supply produces electrical discharges with fast pulse rise time (the minimum is about 50 ns), high pulse peak voltage (maximum: about 80kV) and the pulse repetition frequency 20 to 200 pulse/s. The dusts were investigated to receive highest electrical charge using the power supply mentioned above for effective electrostatic precipitation. The toxic gases were decomposed sufficiently with the corona pulse characteristics: pulse rise time less than about 100 ns, pulse peak voltage over about 25 kV, and pulse frequency over about 60 pulse/s. The dust charge per mass was bigger at slower pulse rise time (a few hundred ns), 20 to 35 kV pulse peak voltage and higher pulse frequency (over 100 pulse/s) in the case of fly ash. The authors' research indicated the possible application of pulse corona for dusty gas cleaning.

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